MILITARY MEDICAL MANUALS

GENERAL EDITOR:
SURGEON-GEN. SIR ALFRED KEOGH
G.C.B., M.D., F.R.C.P.

TREATMENT OF FRACTURES

R. LERICHE
EDITED BY
F. F. BURGHARD

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THE TREATMENT OF FRACTURES

VOL. II

M.S.
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THE TREATMENT OF FRACTURES

BY

R. LERICHE

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EDITED, WITH A PREFACE, BY

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II

FRACTURES OF THE SHAFT

WITH 156 ILLUSTRATIONS

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GENERAL INTRODUCTION

The infinite variety of injuries which any war presents to the surgeon gives to military surgery a special interest and importance. The special interest and importance, in a surgical sense, of the great European War lies not so much in the fact that examples of every form of gross lesion of organs and limbs have been seen, for if we read the older writers we find little in the moderns that is new in this respect, but is to be found in the enormous mass of clinical material which has been presented to us and in the production of evidence sufficient to eliminate sources of error in determining important conclusions. For the first time also in any campaign the labours of the surgeon and the physician have had the aid of the bacteriologist, the pathologist, the physiologist, and indeed of every form of scientific assistance, in the solution of their respective problems. The clinician entered upon the great war armed with all the resources which the advances of fifty years had made available. If the surgical problems of modern war can be said not to differ sensibly from the campaigns of the past, the form in which they have been presented is certainly as different as are the methods of their solution. The achievements in the field of discovery of the chemist, the physicist, and the biologist have given the military surgeon an advantage in diagnosis and treatment which was denied to his predecessors, and we are able to measure the effects of these advantages when we come to appraise the results which have been attained.

But although we may admit the general truth of these statements, it would be wrong to assume that modern scientific knowledge was, on the outbreak of the war, immediately useful to those to whom the wounded were to be confided. Fixed principles existed in all the sciences

auxiliary to the work of the surgeon, but our scientific resources were not immediately available at the outset of the great campaign; scientific work bearing on wound problems had not been arranged in a manner adapted to the requirements—indeed, the requirements were not fully foreseen; the workers in the various fields were isolated, or isolated themselves, pursuing new researches rather than concentrating their powerful forces upon the one great quest.

However brilliant the triumphs of surgery may be—and that they have been of surpassing splendour no one will be found to deny—experiences of the war have already produced a mass of facts sufficient to suggest the complete remodelling of our methods of education and research.

The series of manuals, which it is my pleasant duty to introduce to English readers, consists of translations of the principal volumes of the " Horizon " Collection which has been appropriately named after the uniform of the French soldier.

The authors, who are all well-known specialists in the subjects which they represent, have given a concise but eminently readable account of the recent acquisitions to the medicine and surgery of war which had hitherto been disseminated in periodical literature.

No higher praise can be given to the Editors than to say that the clearness of exposition characteristic of the French original has not been lost in the rendering into English.

MEDICAL SERIES

The medical volumes which have been translated for this series may be divided into two main groups, the first dealing with certain epidemic diseases, including syphilis, which are most liable to attack soldiers, and the second with various aspects of the neurology of war. The last word on *Typhoid Fever*, hitherto " the greatest scourge of armies in time of war," as it has been truly called, will be found in the monograph by MM. Vincent and Muratet, which contains a full account of recent progress in bacteriology and epidemiology as well as the clinical features

of typhoid and paratyphoid fevers. The writers combat a belief in the comparatively harmless nature of paratyphoid and state that in the present war hæmorrhage and perforation have been as frequent in paratyphoid, as in typhoid fever. In their chapter on diagnosis they show that the serum test is of no value in the case of those who have undergone anti-typhoid or anti-paratyphoid vaccination, and that precise information can be gained by blood cultures only. The relative advantages of a restricted and liberal diet are discussed in the chapter on treatment, which also contains a description of serum-therapy and vaccine-therapy and the general management of the patient.

Considerable space is devoted to the important question of the carrier of infection. A special chapter is devoted to the prophylaxis of typhoid fever in the army. The work concludes with a chapter on preventive inoculation in which its value is conclusively proved by the statistics of all countries in which it has been employed.

MM. Vincent and Muratet have also contributed to the series a work on *Dysentery, Cholera, and Typhus* which will be of special interest to those whose duties take them to the Eastern Mediterranean or Mesopotamia. The carrier problem in relation to dysentery and cholera is fully discussed, and special stress is laid on the epidemiological importance of mild or abortive cases of these two diseases.

In their monograph on *The Abnormal Forms of Tetanus*, MM. Courtois-Suffit and Giroux treat of those varieties of the disease in which the spasm is confined to a limited group of muscles, *e.g.* those of the head, or one or more limbs, or of the abdomino-thoracic muscles. The constitutional symptoms are less severe than in the generalised form of the disease, and the prognosis is more favourable.

The volume by Dr. G. Thibierge on *Syphilis and the Army* is intended as a *vade mecum* for medical officers in the army.

Turning now to the works of neurological interest, we have two volumes dealing with lesions of the peripheral nerves by Mme. Athanassio-Benisty, who has been for

several years assistant to Professor Pierre Marie at La Salpêtrière. The first volume contains an account of the anatomy and physiology of the peripheral nerves, together with the symptomatology of their lesions. The second volume is devoted to the prognosis and treatment of nerve lesions.

The monograph of MM. Babinski and Froment on *Hysteria or Pithiatism and Nervous Disorders of a Reflex Character* next claims attention. In the first part the old conception of hysteria, especially as it was built up by Charcot, is set forth, and is followed by a description of the modern conception of hysteria due to Babinski, who has suggested the substitution of the term "Pithiatism," *i.e.* a state curable by persuasion, for the old name hysteria. The second part deals with nervous disorders of a reflex character, consisting of contractures or paralysis following traumatism, which are frequently found in the neurology of war, and a variety of minor symptoms, such as muscular atrophy, exaggeration of the tendon reflexes, vasomotor, thermal and secretory changes, etc. An important section discusses the future of such men, especially as regards their disposal by medical boards.

An instructive companion volume to the above is to be found in the monograph of MM. Roussy and Lhermitte, which embodies a description of the psychoneuroses met with in war, starting with elementary motor disorders and concluding with the most complex represented by pure psychoses.

SURGICAL SERIES

When the present war began, surgeons, under the influence of the immortal work of Lister, had for more than a quarter of a century concerned themselves almost exclusively with elaborations of technique designed to shorten the time occupied in or to improve the results obtained by the many complex operations that the genius of Lister had rendered possible. The good behaviour of the wound was taken for granted whenever it was made, as it nearly always was, through unbroken skin,

and hence the study of the treatment of wounds had become largely restricted to the study of the aseptic variety. Septic wounds were rarely seen, and antiseptic surgery had been almost forgotten. Very few of those who were called upon to treat the wounded in the early autumn of 1914 were familiar with the treatment of grossly septic compound fractures and wounded joints, and none had any wide experience. To these men the conditions of the wounds came as a sinister and disheartening revelation. They were suddenly confronted with a state of affairs, as far as the physical conditions in the wounds were concerned, for which it was necessary to go back a hundred years or more to find a parallel.

Hence the early period of the war was one of earnest search after the correct principles that should be applied to the removal of the unusual difficulties with which surgeons and physicians were faced. It was necessary to discover where and why the treatment that sufficed for affections among the civil population failed when it was applied to military casualties, and then to originate adequate measures for the relief of the latter. For many reasons this was a slow and laborious process, in spite of the multitude of workers and the wealth of scientific resources at their disposal. The ruthlessness of war must necessarily hamper the work of the medical scientist in almost every direction except in that of providing him with an abundance of material upon which to work. It limits the opportunity for deliberate critical observation and comparison that is so essential to the formation of an accurate estimation of values ; it often compels work to be done under such high pressure and such unfavourable conditions that it becomes of little value for educative purposes. In all the armies, and on all the fronts, the pressure caused by the unprecedented number of casualties has necessitated rapid evacuation from the front along lines of communication, often of enormous length, and this means the transfer of cases through many hands, with its consequent division of responsibility, loss of continuity of treatment, and absence of prolonged observation by any one individual.

In addition to all this, it must be remembered that in

this war the early conditions at the front were so uncertain that it was impossible to establish there the completely equipped scientific institutions for the treatment of the wounded that are now available under more assured circumstances, and that progress was thereby much hampered until definitive treatment could be undertaken at the early stage that is now possible.

But order has been steadily evolved out of chaos, and many things are now being done at the front that would have been deemed impossible not many months ago. As general principles of treatment are established it is found practicable to give effect to them to their full logical extent, and though there are still many obscure points to be elucidated and many methods in use that still call for improvements, it is now safe to say that the position of the art of military medicine and surgery stands upon a sound foundation, and that its future may be regarded with confidence and sanguine expectation.

The views of great authorities who derive their knowledge from extensive first-hand practical experience gained in the field cannot fail to serve as a most valuable asset to the less experienced, and must do much to enable them to derive the utmost value from the experience which will, in time, be theirs. The series covers the whole field of war surgery and medicine, and its predominating note is the exhaustive, practical and up-to-date manner in which it is handled. It is marked throughout not only by a wealth of detail, but by clearness of view and logical sequence of thought. Its study will convince the reader that, great as have been the advances in all departments in the services during this war, the progress made in the medical branch may fairly challenge comparison with that in any other, and that not the least among the services rendered by our great ally, France, to the common cause is this brilliant contribution to our professional knowledge.

A glance at the list of surgical works in the series will show how completely the ground has been covered. Appropriately enough, the series opens with the volume on *The Treatment of Infected Wounds*, by A. Carrel and G. Dehelly. This is a direct product of the war which,

in the opinion of many, bids fair to become epoch-making in the treatment of septic wounds. It is peculiar to the war and derived directly from it, and the work upon which it is based is as fine an example of correlated work on the part of the chemist, the bacteriologist, and the clinician as could well be wished for. This volume will show many for the first time what a precise and scientific method the "Carrel treatment" really is.

The two volumes by Professor Leriche on *Fractures* contain the practical application of the views of the great Lyons school of surgeons with regard to the treatment of injuries of bones and joints. Supported as they are by an appeal to an abundant clinical experience, they cannot fail to interest English surgeons, and to prove of the greatest value. It is only necessary to say that *Wounds of the Abdomen* are dealt with by Dr. Abadie, *Wounds of the Vessels* by Professor Sencert, *Wounds of the Skull and Brain* by MM. Chatelin and De Martel, and *Localisation and Extraction of Projectiles* by Professor Ombrédanne and R. Ledoux Lebard, to prove that the subjects have been allotted to very able and experienced exponents.

ALFRED KEOGH.

EDITOR'S PREFACE

The contents of this volume are certain to give rise to considerable controversy. The book emphasises the doctrine of the Lyons school that in septic fractures loose fragments are not only useless, but are a source of danger and should be removed sub-periosteally at the earliest available opportunity. This principle of "immediate prophylactic total sub-periosteal esquillectomy," to give it its full title, is widely opposed to the view prevailing among British surgeons, with whom it is the practice to remove none but fragments obviously devoid of all attachment to soft parts. Indeed this practice has been carried to such an extent by some surgeons that loose fragments have actually been removed, cleansed, and returned to the wound. To those who hold this view Professor Leriche addresses himself forcibly, clearly, and with a wealth of clinical experience to back his opinions that makes his case a very strong one.

The case for esquillectomy that he sets out in this book is one that can only be met by statistics. Sufficient time has now elapsed for enough clinical material to be available upon which to base a sound judgment, and it is to be hoped that before long an accurate conclusion may be come to between two views which are so widely divergent. While I do not feel myself to be in a position to attempt such a serious undertaking, I am bound to confess that what experience I have had of the methods Professor Leriche advocates leads me to think favourably of them, while on the other hand the immense number of cases of long pro-

tracted complications in the form of sinuses, sequestra, and vicious callus that one is called upon to treat in cases in which fragments have been left undisturbed *in situ* make me ready to extend a most sympathetic consideration to a method of treatment which claims to do away with such distressing hindrances to recovery.

Put concisely, the position is that one school regards as its bugbear a possible want of union as a result of the removal of fragments from an infected fracture, while the other attaches prime importance to the persistent suppuration and loss of function to which the retention of septic fragments is so likely to lead. Having regard to the comparative ease with which the surgeon can remedy non-union and the often insuperable difficulties in his path when he has to deal with diseased union, there can be little doubt in the mind of a dispassionate observer as to which risk it is preferable to run, for non-union is a far less serious matter than a diseased callus.

Professor Leriche goes on to show from his own practice that non-union need not be feared if the treatment of the fracture be upon sound and definite lines and carried out with the care and skill for which he is so strenuous an advocate. I am sure that one result of the publication of this very important work will be to give a stimulus to the treatment of fractures and to enable us to arrive at conclusions of great importance. It must necessarily make all operating surgeons inquire whether they cannot better the results that they are in the habit of obtaining.

Of the book itself I need say little. It is sure to be very widely read, and I am certain that every one who reads it will be in agreement with the author's views upon the absolute necessity of what he terms "prophylactic intervention." The certainty of infections of the most fatal type in these deep-seated wounds, and the impossibility of securing adequate cleansing of them without wide and comprehensive operation, are

points only too familiar to those who have had experience at first hand of these most serious cases, and his plea for immediate operation even in cases that are apparently quite benign, on account of the impossibility of foretelling what may happen in twenty-four hours' time will be fully endorsed by all those working at the Front.

There is much in this book that every surgeon may read with profit, for it deals not only with general principles of great importance, but it goes into great detail concerning every kind of fracture likely to be met with in practice. The mechanical treatment of the various fractures too is full of interest and quite up to date as well as being especially suited for those working in the actual battle-area. There are several methods that will probably be new to English surgeons.

If I may venture to say so, Professor Leriche has done good service to military surgery by the publication of this excellent work on injuries to bones and joints.

F. F. Burghard.

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INTRODUCTION

Physiological Principles underlying the Surgery of Fractures in War

MANY surgeons consider the treatment of fractures of the shaft received in action a thankless, annoying, and difficult task. Confusing, by a strange mistake, two things which are by no means parallel, anatomical recovery and functional recovery, they imagine that conservative surgical treatment consists in retaining in the injured area the greater part of the osseous débris which they find there. For this reason they fail to cleanse thoroughly the bone lesions which they are treating, and direct their attentions chiefly to mechanical treatment. Ignoring the surest lessons of experimental surgery, they dare not put their trust in physiology, and sincerely believe that splinters of diseased or dead bone are useful aids to bone formation. Their cases suppurate, sequestra work their way out, sinuses are formed, and when union at last occurs, troublesome after-effects persist and contribute to the serious interference with function occasioned by the sclerosis and atrophy of muscles.

This little volume is written from an entirely different point of view. As in the volume which I devoted to articular fractures, each page will be found to develop the view that the essential point in treating fractures is early removal of infection by a comprehensive operation based on definite physiological theories.

Fractures, like all properly treated gunshot wounds, should not suppurate if they are speedily cleansed; esquillectomy (removal of fragments) suffices to ensure

this in the fracture, as does excision in wounds of the soft parts.

The case should be removed at once from all risk of infection, and nothing should subsequently be permitted to interfere with the normal function of bone-forming elements at the seat of the fracture. Failing this, conservation can scarcely be mentioned without irony; the patient is left with a pitiful limb, covered with scars and riddled with sinuses, and with sclerosed muscles without either strength or suppleness. The new bone should be healthy bone, formed from fresh elements into a regular callus with nothing pathological in its nature. Sub-periosteal esquillectomy can alone assure this essential development; if carried out thoroughly, it reduces the wound to regular proportions and guarantees sufficient asepsis; if carefully conducted, rugine in hand, with the consistent intention of reflecting the periosteum from everything that seems to demand removal, it repeats Ollier's classical experiment, and early assures the desired physiological result.

I cannot understand how a fact so well established by experience can still be discussed at the present time: it is neither paradoxical nor revolutionary; it is compatible with the traditional teachings of classical physiology; it can be verified at leisure every day. Why meet so obvious a proposition with specious arguments when direct verification is always possible?

It will perhaps be said that careful experiments afford evidence unfavourable to the method; that in many esquillectomies, flail-joints or incurable false joints have been formed. On this pitiable evidence it is decided that the sub-periosteal removal of fragments is useless. Need one point out the worthlessness of these careless conclusions? What is known of the conditions under which the operations were performed? The greater part were merely extra-periosteal resections. And in the cases where actual removal of fragments was practised, it is impossible to say whether this was

sub-periosteal. On the contrary, it would seem that these limbs which have never recovered are like those of the animals upon which Ollier, more than fifty years ago, performed extra-periosteal resection to demonstrate by comparison the part played by the periosteum in osseous regeneration.

Agreeable or not, there are definite facts which are sometimes forgotten, but which in the past established the laws of bone-formation. They are the following :

(1) In young subjects, if the bone is removed and the periosteum left, the latter invariably reproduces an osseous mass clearly of the same shape and size as the portion of bone removed. The regularity of the new bone depends on the support given to the periosteum in its original situation. No regeneration occurs if the periosteum is removed, and its activity is destroyed by any virulent infection.

(2) When growth has ceased, *i.e.* after the twenty-second or twenty-third year, the periosteum loses all activity ; but under certain circumstances (a violent injury, repeated small injuries, or the irritation of a moderate infection) it resumes its osteogenetic activity. Under these conditions regeneration occurs in proportion to the extent of periosteum saved ; the amount of bone formed is scarcely less than what has been removed, if the removal has been thoroughly sub-periosteal, and if the gap between the fragments has been preserved in its original extent ; regeneration is poor and incomplete if the operation has not been thoroughly sub-periosteal ; there is none at all, if it has been extra-periosteal.

Since 1858 no facts have been found to upset these laws ; all experimenters and surgeons *who have placed themselves under the same conditions as Ollier*, all who have sought, beneath the fibrous periosteum with a cutting rugine, for the fertile periosteum, have obtained the results which he announced.

War, in affording enormously greater opportunities

for observation and study, has brought no discordant note; it has rather shown to those who cared to see that the periosteum, if not killed by infection, is even more fertile than they had ventured to suppose; its proliferative activity in the young male whose normal growth is just at an end, and the revival of its constructive properties in the adult, have become facts of daily experience.

In clinically infected fractures, two, three, or four days after the receipt of the wound, sub-periosteal esquillectomy is invariably followed by bone formation excellent both in shape and in rapidity, immediately following the fall of the temperature and the disappearance of the infective symptoms.

More than this—in the very early stages, previous to all clinical evidence of infection—the violence of the injury, extensive sub-periosteal hæmorrhage, and the rapid appearance of reaction against an aggressive local infection, combine to stimulate the quiescent bone-forming tissue. In adults of full physical vigour, the periosteum very shortly resumes its ability to form bone, *provided that no clumsy injury by an over-zealous operator destroys the delicate seat of its fertility.* I emphasise these words, for the restraint which they advise is of paramount importance. Sub-periosteal esquillectomy at any stage, but above all as an early operation, should not be a brutal act; I should imagine that no surgeon would care to apply this rather strong term to himself, but yet how many deserve it! If the results mentioned are to be attained, the esquillectomy to be effected calls for the exercise of as much minute care and patience as an intestinal or nerve operation: it is one to be carried out with small and delicate instruments, manipulated in a good light with the wound widely open, and not blindly with large cutting or gripping forceps; forceps with serrated edges, such as are used for calculi, and a good Ollier rugine, are sufficient for all that need be done, but

the work demands precision. The edge of the rugine should move slowly but surely ; it is work for fingers and wrist, not an exercise for the elbow.

Let there be no mistake, this is the whole secret of success. One can safely foretell that certain over-hasty surgeons will achieve nothing from sub-periosteal esquillectomy, and will condemn the method. They should condemn themselves, and compel themselves to change their own methods. There is one way and one only of using the rugine ; with it brilliance and display are impossible, but it is reliable. Ollier was a very slow operator, of great patience, but his rugine effected everything ; he achieved, too, results which were unknown before him ; his pupils have been similarly successful whenever they have followed his methods and exercised the same minute care.

One should be inspired by his traditions and learn his methods, instead of adapting to rational surgery the brilliant, but in this connection hateful, procedures of the dissecting-room. It is not a difficult matter, not a brilliant feat, but an exercise of patience. After all the result justifies the effort ; in operating thus, in restraining his hand and checking his impulses, the surgeon who carries out a thorough sub-periosteal esquillectomy with an eye to the physiology of ultimate recovery will be rewarded by rapid aseptic progress of the wound and regular union of the fracture.

A final question should be asked : at what stage is the activity of adult periosteum fully resumed ?

There is material here for interesting research. Ollier wrote that hyperplasia in the periosteum became visible towards the fourth day ; that at that time, with a periosteum thickened and œdematous, the operation was *anatomically* easy. It should not be concluded that it is necessary to wait so long, for the periosteum is physiologically utilisable much earlier than this ; functional modification invariably precedes anatomical alteration visible to the naked eye. It is

after all reasonable that changes should be histologically demonstrable much earlier; the periosteum should react like the soft tissue from which it originates, and Policard and Phélip have shown that in such a case the first signs of an organic reaction appear about five hours after the injury. I do not know whether the periosteum is equal to its task at this stage, having never followed the progress of a fracture operated on before the twelfth hour long enough to determine the point. But I know well that after twelve hours the periosteum has practically regained its activity, and Sencert, Cotte, and Santy, who have frequently operated within the first few hours after injury, have never seen bone-formation fail to occur.

It would doubtless be interesting and useful to have a classification of periosteal changes, but in practice this is of smaller importance than would appear. Under ordinary war conditions operation during the first twelve hours is, and never will be, anything but the exception. Obviously, in certain quiet sectors, it may occur fairly often, but the few cases seen there are nothing to the formidable numbers on fighting fronts.

The rule I am about to lay down applies to an ambulance stationed in an active sector, for there it is impossible to await clinical indications if the prevention of infection is to be ensured.

Now in this position, which is that of the large majority of operators, and those treating the largest number of wounded, how many operations can be performed in the first twelve hours, taking into account the difficulties of collection, barrage fire, and the fatigue of endless operations ?

In concentrating on exceptional cases, one very simple question must not be obscured. When the right moment can be chosen, nothing could be better than to wait some hours in order to operate under more favourable conditions, and to perform the esquillectomy in two separate stages, thereby producing a

more fertile periosteum, but this is not proposed as an example to be followed invariably. It is at best a dangerous risk, as too long a delay may result in the destruction of the periosteum by infection. Therefore, in all other circumstances, sub-periosteal esquillectomy should always be performed at once for prophylactic reasons; it is also physiologically justified, for the irritation produced by methodical scraping, and the plugging of the seat of injury, are sufficient to re-activate the periosteum, and union results regularly.

After such an operation, all subsequent treatment is so simplified that this in itself is a recommendation of the method; local progress being uneventful, *our efforts can be directed to ensuring the regularity of the callus which is forming*; a serious and complicated fracture progresses in the same way as a simple closed one. And when, after the union has become firm, attention is given to the restoration of function, no sclerosis interferes with the play of muscles and joints, and movement is recovered with ease.

For these reasons and no others I have in this book continually recommended sub-periosteal esquillectomy as the first step in the earliest stages in treating fractures requiring operation.

But obviously esquillectomy is not all.

That the new bone may grow in the right direction, the fracture must be reduced, the axes of the two parts of the broken shaft must correspond, displacement and rotation must be corrected. To prevent any inflammatory outbreak in the growing bone, all movement likely to injure the fragments must be avoided; absolute immobility and continuous extension are the indispensable accompaniments of this method and the conditions necessary for an uneventful progress.

I have shown in the case of each type of fracture the means by which I am accustomed to prevent movement; I have proposed only simple, well-tried devices, which are easily improvised. It must not be forgotten,

indeed, that the war-surgery is largely done at the front, and will continue to be more and more so in the future. The appliances recommended can be obtained everywhere, and they have been sufficient for me in all circumstances. There are others, both excellent and ingenious, not enumerated here. At the risk of an accusation of incompleteness, I have only mentioned those of which I have had experience, without trying to exhaust the subject.

This book, simple and practical, written in rare hours of leisure from ceaseless and pressing work, is concerned only with fractures of the shafts of long bones. In each type I have discussed successively: anatomical features; physiological features; clinical course; indications for early treatment*; operative technique; the treatment of cases examined at a late stage or already under treatment.

These distinctions are perhaps rather arbitrary, and will appear more definite in the text than they are in the actual cases themselves. I am aware of this, and have systematically avoided transitiona types in a constant endeavour to write clearly. But in the very simple design which I have outlined, each will find it easy to insert variations in detail; these will agree, I am sure, with the main rules of treatment that I have developed, and the physiological conclusions which have guided them.

I shall perhaps be blamed for not having considered Carrel's method. I have wished to discuss only what I have seen personally, in working with an active ambulance unit obliged to carry out rapid evacuations. All necessary details will be found in the work which has appeared in the present series.†

* I have only been able to give a limited number of X-ray photographs concerned with primary esquillectomies, my personal observations dating from a time when X-ray photography did not exist in the Army Medical Service.

† *The Treatment of Infected Wounds*, by A. Carrel and G. Dehelly (Military Medical Manuals, published by the University of London Press, Ltd).

THE
TREATMENT OF FRACTURES

VOL. II

FRACTURES OF THE SHAFT

CHAPTER I

A GENERAL STUDY OF SHAFT FRACTURES

Apart from the formidable crushing of limbs, with complete shattering of bone and extensive destruction of muscles, blood-vessels, and nerves, such injuries, in fact, as can scarcely be studied as fractures, there are in war surgery, *from the point of view of treatment*, only two great types of shaft fracture: *those produced by long-range bullets*, which strike the limb in the ordinary way, point first, perforating the soft parts and only producing very small wounds as they pierce the skin, and *those caused by other projectiles, short-range bullets, or the explosion of shells, bombs, mines and torpedoes, etc.*

The former progress like simple fractures, do not suppurate, and are not liable to serious infection: they get well easily and quickly. These were once regarded as the ordinary type of war-fracture.

The latter are always infected at the outset, and the development of the infection, though always a

matter for concern, varies in the severity of its results.*

The former are becoming more and more rare in modern warfare even during fighting in the open. No operation, or at least no early operation, should be performed; absolute immobility and continuous extension suffice for recovery. This type will receive little discussion in this book, which concerns itself principally with surgery at the front.

The latter form an enormous proportion of our cases nowadays; the operation of sub-periosteal esquillectomy † should be performed systematically as early as possible; in this way all complications that threaten will be avoided, and further progress will be aseptic and end in good union and healing.

It is with this type that I am henceforth concerned.

I must first, however, enumerate the points which distinguish the two types. As a matter of fact, only the nature of the wound of entry need be noted; there is no other means of forming a conclusion, and this one is satisfactory in itself. The skin wounds are very small and insignificant, suggesting, at the points both of entry and of exit, the appearance of a trochar puncture: they are "punctiform" wounds, to use the convenient term which Ferraton has brought into general use. The wound of exit is scarcely larger than the wound of entry: if it is larger than a cherry stone there is some danger of a slight infection, certainly not always, but frequently to a sufficient degree to prevent closure for some time; if it should be as

* Wounds by shrapnel bullets are decidedly less serious than those caused by shell-fragments. They are, in a sense, intermediate between the two groups described above. But though their suppuration is sometimes benign, it can be and frequently is very serious; they should therefore undoubtedly be studied in the category of fractures by shell explosion.

† This term will be used throughout, as in Vol. I, to denote the removal of bony fragments and splinters after separation from their periosteal covering.—Ed.

large as a shilling, infection is, if not invariable, at least usual.

These "punctiform" wounds must have been caused by bullets only; the insignificant little wound sometimes produced by a shell- or bomb-fragment is as serious as a large wound, if not more so, for, although it appears a small matter from the exterior, there are extensive injuries within.

What is to decide whether we are dealing with a bullet wound or not? The patient's own statement is not enough, as he may easily be mistaken, but a careful examination will usually reveal the truth.

A bullet fired at long range and entering nose first leaves behind it no such track of bruised tissues as is caused by a shell-fragment; the skin wound is clean and not gaping. Anyone who has seen a few fresh wounds will never be mistaken. A bullet, too, which, though it may have travelled some distance, enters with sufficient force to penetrate bone, rarely remains embedded, it almost always passes out; whereas a small shell-fragment usually remains in the wound; besides which, a wound of the latter type is rarely single, there being almost always others somewhere in the region of the small wound corresponding to the seat of the fracture. These distinguishing characteristics, slight as they may seem at first, are perfectly clear, and rarely cause hesitation.

Having said this, I shall now only speak of fractures caused by shell-fragments or short-range bullets.

In spite of the infinite variety of metallic fragments of all kinds, these different fractures correspond very closely in their features, and scarcely need be distinguished.

I shall therefore study them together, treating first, from a general point of view, of *the immediate pathological anatomy of the seat of the fracture*, then of *the course of events in the injured area*.

As the course of events is controlled by *infection*, it

will be well to investigate the circumstances contributing to infection, and the anatomical results of its presence. A knowledge of what is to be feared will show clearly what is to be avoided.

I. Pathological Anatomy of the seat of a Fracture in its earliest stage

Every projectile striking the shaft of a bone does not of necessity fracture it : *there is no fracture unless the continuity of the shaft is broken.*

Injuries by missiles which do not cause solution of

FIG. 1.—Transverse fracture.

FIG. 2.—The large-splinter type of fracture.

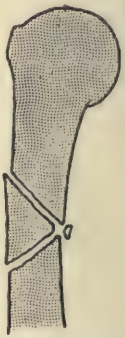


FIG. 3.—Fracture with a large short fragment.

continuity in the long axis of the bone are merely *wounds* of the bone, whatever their form or appearance, whether pitting, furrow, or tunnelling.

Fractures rightly so-called exist in infinite variety, and may be roughly grouped into several types : these main groups can easily be distinguished after examining a large number of X-ray photographs.

The four most important are :

1. *The transverse type* (*unusual*).—This fracture has only one direction, resembling the result of deliberate section of the bone. It may be slightly oblique, but is more often exactly transverse. This fracture is usually produced by the impact of a large shell-fragment, almost spent, which enters the bone like a wedge.

2. *The large-splinter type* (*common*). — There is considerable splintering of the bone in the direction of its length, with one or two large diamond-shaped fragments, the centre of which is roughly the point of origin of the fracture. In other words, the two ends of the shaft taper to points which are in contact, the splinters formed being lodged in the angle which they enclose. Each splinter, about 4 to 6 inches in length, is sometimes split across its centre. There is usually little displacement.

This tapering of the two ends of the shaft is rarely seen except in the femur and humerus.

3. *The type with a large short fragment* (*common*).—In this type, usual in the ulna and tibia, a short and broad wedge-shaped fragment is detached from the shaft and remains in place between the two obliquely pointed extremities of the shaft. The appearance of the whole thing is that of a horizontal V. Sometimes two or three small pieces are found, like little beads, on the side opposite to the main fragment. There are very often fissures extending along the shaft in each direction.

4. *The type with many small fragments* (*common*).—In this fracture the shaft is shattered into a large number (12, 15, or more) of small pieces, more or less obviously radiating from the point of impact. Some, from the middle of the seat of fracture, are entirely free, forced away some distance from the bone, often embedded in muscles, thereby contributing to their laceration, and of no regular shape. Above and below, in contact with the ends of the shaft, fragments

remain adherent to the periosteum or muscles, and these, though fewer in number, are usually rather larger than the others. The general impression given is that a mass of small fragments has been impelled in the direction of the exit wound, or at least pushed by the missile in front of itself. There is generally small débris embedded in the surrounding muscles.

FIG. 4.—Fracture with many small fragments.

One of these types will be recognised in any fracture examined by X-rays or by operation.

Others might be described, notably spiral fractures occurring at the lower end of the tibia, or the V-shaped fractures sometimes seen in the lower third of the humerus, femur, and tibia. All, however, can be relegated more or less rightly to the above categories, or else can be regarded merely as exceptions.

To go into more detail: the fractured area first comprises the following elements:

1. **The Fragments.**—These occur in all sizes and shapes, from mere bone dust to large diamond-shaped fragments 6 inches long.

The smaller they are, the freer they are found to be from all attachment to periosteum or muscle, and the further they are found from the line of the shaft. In general, small fragments are projected distally towards the point of exit, or more exactly, in the same direction as the track of the missile, intra-osseous and otherwise.

This has a practical result of great importance: the first fragments which the projectile pushes forward in traversing the bone end by embedding themselves in the marrow of the shaft at some distance from the point of impact, above all in the spongy tissue of the

epiphyses, thus evading discovery unless their actual position is known. Virtually foreign bodies, they remain in the middle of the injured marrow. Other pieces lacerate muscles and remain embedded there.

Given sufficient impetus, they may happen to lacerate vascular sheaths, and come to rest in contact with arteries and veins, whose elasticity deadens the blow; hence they are very rarely perforated by the original injury. Nerves, being more resistant, are more readily torn or severed. It is not unusual, for instance, to find minute pieces of bone in the sciatic nerve.

When the force of the blow is not so great, the fragments are larger; they remain more or less attached to the periosteum and surrounding muscles. They are lodged in the periphery of the injured area, more or less scattered, sometimes directed towards the point of exit. The larger they are, the more they resist the injuring force whose tendency is to displace them, without actually freeing them altogether from their ligamentous and periosteal attachments. The most adherent are those which an intact periosteum retains in perfect continuity with the rest of the shaft, narrow fissures alone dividing them from it. There are, in fact, all degrees between a free fragment, entirely detached, and the most adherent one; if only two extreme forms are distinguished, no clear understanding of the anatomical details in the fractured area is likely to be reached; this arbitrary distinction has accounted for regrettable mistakes in treatment, and still produces unfortunate confusion in surgical discussion.

Small scraps of clothing often remain caught on the sharp points of long splinters—not the main piece of material which the projectile has carried before it through the bone, but shreds torn away as it passes. They are sometimes embedded and scarcely movable in the crevice between two very adherent fragments, and it is exceedingly difficult to detach them.

The points of splinters, too, and likewise the ends of the shaft, are bruised, crushed, and inflamed, affected by what is sometimes called traumatic osteitis; in fact, they are more or less devitalised by the force of the impact.

In the crevices separating the splinters there is almost always a thin trail of blood-clots, and often, in contact with them, metallic particles which had accompanied the main shell-fragment.

A little cancellous tissue, stained purplish or black with effused blood, is seen on the internal aspect of almost all the splinters.

2. **Fissures.**—There are usually fissures travelling away from the injured area, caused by the spreading of the projectile's energy on impact. In different ways, according to the intensity of this energy, and the particular bone or region, these fissures, instead of meeting and thus forming separate splinters, often run parallel for a variable distance along the shaft towards the epiphyses. If they are very marked, X-rays will reveal them, but more often they are only discovered by careful direct examination; some even appear only on transverse section of the bone.

In fractures occurring close to joints these fissures are very common; their existence explains the appearance of joint symptoms at some distance from the fracture, and accounts for certain complications to which I shall refer later.

In an aseptic wound fissures are of no consequence, and union soon occurs, nothing of them being visible after a few days. But if there is the slightest trace of infection in the main wound, this spreads along the clefts, and gradually reaches the joint cavity, particularly in the case of a fracture below the epiphysis of the humerus or femur.

Apart from such fissures, a second fracture of the shaft is occasionally found at some distance from the other and in a healthy area, generally serrated so that

the ends fit with comparative accuracy. I have seen this in the humerus and femur.

3. **The Medulla.**—At the level of the track of the missile, the delicate marrow seems, as it were, to have evaporated ; no trace of it is found except a few masses of blood-stained pulp on the inner side of some splinters. But above, along the large fragments whose arrangement indicates the position of the medullary cavity, it is found to be torn up and bruised for a great distance. Small extravasations of blood are seen high up in the interior of the shaft, at points which would at first appear not to have been affected by the injury. These widespread contusions are produced in the same way as the radiating fissures mentioned above, and have the same untoward results.

FIG. 5.—Example of fracture with long fissures.

The scattering of small splinters into the medullary cavity further increases the extent of the injured area, shattering the network of cancellous tissue and leaving splinters buried in it.

4. **The Periosteum.**—This is sometimes destroyed where the projectile has reduced the bone to fine splinters and scattered them widely. These lose their periosteum, but it is a mistake to suppose that nothing remains of this membrane which previously united them. The periosteum remains for the most part in irregular fragments which at first appear to maintain no independent existence. Further up the bone they are found to be raised in places by blood-clots, detached

by an extensive effusion of blood, or displaced by muscular action, partially isolated, in fact, from fragments that have remained in position. Further on, the periosteum is still adherent to the fragments of bone, isolated and apparently mobile though they may be; more or less lacerated in the region of the fissures, it is much more often intact farther from the seat of injury than it is believed to be. It is always delicate, appearing to be a part of the bone; many surgeons suppose that it cannot be separated from the latter, and that without infection to thicken it, the periosteum is surgically non-existent. This conclusion saves them the trouble of looking for it. But for the careful operator, using the sharp rugine, the periosteum always exists, and can always be isolated. Like all fibrous tissues, it is very resistant, and, in the main, it suffers less than any other part of the bone from the passage of the missile. This is well demonstrated during the operation for sub-periosteal esquillectomy; when, approaching the fracture from the exit wound, free splinters, shreds of muscle, and clots have been removed, and as soon as one or two splinters have been detached that had been maintained in position by the periosteum, it is clearly seen that

FIG. 6.—Double fracture of the humerus, one direct caused by a shell-fragment and a jagged indirect fracture below it. Early sub-periosteal esquillectomy of the fractured area has permitted clinically aseptic development. Continuous extension and abduction applied below the fractures has reduced the latter, and union has taken place with a shortening of about 1 inch.

the osseous space is everywhere defined by a fibrous and opalescent sheath. This sheath usually retains its continuity at some point in its circumference ; the injury to it is less considerable at the point of entry than at that of exit, and it forms a kind of mould of the missing portion of bone. Unless great care is taken, or if those splinters are sharply pulled or twisted which seem only weakly adherent, but are often more tenacious than is supposed, nothing of this is seen. Fibrous fragments float freely about on the confines of the fracture, becoming mixed up in shreds of muscle, and it may be said that the periosteum no longer exists. This may be so, but the blame for it lies with the operator.

FIG. 7.—Diagram of a fractured area.

Only in cases of fracture by a short-range bullet, with powerful explosive effects, is there in some parts total destruction of the periosteum, and even here, large flaps of it are found, which when brought together form a kind of sheath with little interruption.

In brief, the region of the fracture, bounded by injured muscles, roughly assumes the shape of an irregular spindle. In the centre is a mass of clots, muscular débris, and small pieces of bone, arranged about its transverse diameter ; at one extremity are free splinters scattered in the soft parts, and converging from the medullary cavity to a point marked by the exit wound. The entire picture is that of a cone, its base turned towards the bone, and bordered above and below by isolated osseous fragments. The fragments still adherent to the periosteum, and connected by it with the shaft, point towards the exterior and

form the axes of the spindle. Above and below, their periosteum encloses the most distant fissures and connects the fragments with the uninjured shaft, somewhat after the manner of a calyx.

At the extremities of its vertical diameter contusions are still found, little as injury might be expected there. Fissures are found in the dense tissue of the shaft, and the bone-marrow is dark with effused blood.

When once the space between the bones is cleared, the periosteum remains like a mould in two vertical pieces, completely encircling the injured area. But it must not be supposed from this that the splinters form a regular bony cylinder whose removal will at once produce a corresponding shortening of the limb. More often, except perhaps in fractures produced by bullets fired at point-blank range, only certain portions of the shaft are splintered. The two pointed extremities of the shaft meet at their apex, and to some extent ensure the continuity of the bone without loss of intervening osseous material, even after removal of all the splinters.

5. **Injuries to the Soft Parts.**—Laceration of these varies a great deal according to the conditions of the wound: a small wound of entry and a large one of exit with hernia of muscle in wounds by short-range bullets, a single insignificant wound from certain fragments of bomb or shell, the cutaneous wound being usually much smaller than the missile causing it, and a large irregular and ragged wound caused by a number of separate shell-fragments.

The wounds are naturally not always opposite the point of fracture. With different angles of incidence, all directions are possible for the track of the missile; when all the possible different positions in which the limb may be when the wound is inflicted are considered, many curious results are observed.

The cutaneous wounds are generally bounded by a zone of crushed and bruised tissue, often impregnated

with soil and shreds of clothing. Very shortly the edges become distinctly ragged. Below this, the fasciæ are torn, often very widely, but as a rule, particularly in certain regions such as the thigh, the upper two-thirds of the leg, and the posterior aspect of the arm and forearm, the entry wound in the fascia is small and its edges are rigid and stretched, gripping a small hernia of muscle which seems to be trying to fill up the track of the missile.

When the injury to the fascia is extensive, the muscles lie immediately beneath the skin; they are more or less lacerated, and rapidly assume the appearance of gangrenous tissue, and often have an unpleasant friable granular feeling to the touch. Small thrombosed veins and blood-clots are found beneath the skin and along the muscles. The more or less gangrenous muscle constitutes a curtain hiding the end of the track where the fracture is situated. In the exit wound the injury is more extensive, and fragments of bone, scattered by the violence of the impact, augment the damage caused by the missile itself.

Muscular involvement extends some distance from the region of the track; sheaths are infiltrated with blood and loosened; fibres severed by the missile retract towards their insertions, extending the effects of the injury for a considerable distance. These are the chief features: widespread muscular injuries, interstitial hæmorrhage here and there and slight evidences of explosive effects, encountered sometimes at points that seem astonishingly remote, even to one accustomed to finding them.

Blood-vessels and nerves are usually uninjured.

Primary injuries of vessels are in the main unusual, except in the arteries of the forearm. Laceration sometimes occurs in the femoral artery in fractures of the upper end of the femur, in the brachial in the upper part of the arm, and in the posterior tibial high up in the leg. Hæmorrhage, however, is not often extensive,

and many injured vessels do not even bleed at all, and the lesion escapes notice at first unless they are disturbed. There are no doubt many which do bleed, but such cases die before reaching an ambulance. Though actual wounds of vessels are unusual, arterial contusions are far from being so. In aseptic wounds they heal without giving rise to any particular symptoms, but if there is any infection, a diseased patch develops, and subsequent ulceration may lead to fatal secondary hæmorrhage.

Nerve lesions are more common. Taking all war-wounds together, however, this complication is an unusual one. It is difficult to state an exact proportion, since a good deal of traumatic paralysis may escape recognition during a large influx of cases. I have counted barely 8 per cent., but this figure is valueless. There are some fractures which never involve nervous lesions, and others in which they are a common feature ; that of the upper third of the humerus, for instance, causes, in my experience, radial (musculo-spiral) paralysis in 16 to 18 per cent. of cases. Ulnar paralysis often complicates fracture of the ulna, and sciatic paralysis sub-trochanteric fracture of the femur. The injury to the nerve is almost always caused by the missile and not by splinters.

6. **Displacement and Over-riding.**—There is usually little displacement in these fractures, relatively at least to the amount commonly seen in civil practice, although the fracture extremities do not fit, and there is always damage to the periosteum ; in some fractures there is no initial displacement whatever, since the partial destruction of muscles and tendinous insertions prevents the exertion of any pull on the fragments of the shaft. At times, on the other hand, there is marked displacement : it may occur in any direction, according to the general position of the bone or bones ; sometimes it produces angulation in

the thickness of the limb (common in the upper third of the forearm), sometimes it produces a sort of bayonet deformity (common in the leg); where two bones are involved, displacement often takes the form of convergence between them, if the fracture occurs in the middle of the shafts (in leg and forearm). Finally, a frequent effect is the rotatory displacement of the two ends of the shaft in opposite directions, resulting from the action of antagonistic muscles, exemplifying what Destot described in civil practice as "décalage": this occurs most typically in the forearm, the upper radial fragment being rotated outwards by the supinating effect of the biceps and supinator brevis, while the pronators induce marked pronation in the lower fragment; the phenomenon occurs in some degree, however, almost anywhere.

Over-riding, which is only longitudinal displacement, is never marked except in the arm and thigh. Here, however, it is often considerable, and the opposed fragments are distinctly pointed; the muscles, in spite of their injuries, are still powerful enough to pull the lower fragment forcibly upwards, thus piercing the muscles and carrying with it a few large splinters which remain interposed between the two ends of the shaft. In fractures high up in the thigh, the upper fragment almost always undergoes abduction and external rotation. Similarly in the upper part of the humerus, if the fracture occurs below the insertion of the deltoid, the proximal end is carried upwards, outwards, and backwards, while the lower suffers internal rotation with a variable amount of displacement towards the axilla.

This may be summed up in the following way: whatever the type of fracture, its effects are always very widespread; injury extends much further than might be supposed; in the centre of the injured area is a mass of clots, muscular débris, and free splinters of bone; above and below it are fragments more or less

displaced, but still attached to periosteum or muscle; some, where periosteum has proved resistant and still invests them, retain their position in relation to the shaft, the sharp points of which are generally in contact with those of the opposite side. Fissures in the shaft itself prolong the injury further. Within the medullary canal, part of whose contents is gone completely, is found a mixture of blood-stained pulp and isolated splinters without muscular attachment and destined ultimately to undergo necrosis.

The fractured area is not usually in a straight line; displacement and over-riding, however, are often not serious. All the surrounding muscles are bruised and lacerated, but they still function and approximate again after the missile has passed, completely enclosing the region of the fracture.

II. Immediate results of Fracture, and the normal course to recovery

Violent local injury producing the effects described above gives rise to a very variable immediate reaction on the system generally.

Some cases show practically none, and exhibit no signs of shock; the patients remain upright and retain consciousness. In the majority of cases it is otherwise, as the initial loss of blood is considerable. At the aid-post and in the field ambulance, hæmorrhage is so profuse that serious vascular injury is instinctively suspected by the less experienced; this explains a good deal of the useless application of tourniquets. Pain and loss of blood combine to produce depression which subsequently disappears if the preliminary steps are taken promptly. Very frequently, too, particularly in fractures of the lower limb and sometimes after very slight loss of blood, severe symptoms of shock are present—pallor, lividity, coldness, and

shivering, sometimes dyspnœa and a feeble rapid pulse —the typical picture of shock.

This is not the result of infection, and does not indicate acute septicæmia, as is sometimes stated; it appears at once, before any infection could have developed, and is, indeed, noticed chiefly in cases which recover without sepsis under suitable treatment; shock is therefore not an evidence of septicæmia. It is apparently the result of sudden vasomotor disturbance following pain reflexes from the wound, of hæmorrhage, and, above all, of sudden injury to branches of the sympathetic system, resulting in violent peripheral vaso-constriction, and corresponding dilatation of the abdominal vessels.

As soon as the pain has passed off and immobility of the injured region has been ensured, the disturbances in the sympathetic system automatically and easily right themselves, producing excellent physiological conditions for spontaneous recovery, should the injury remain aseptic.

There are, in fact, *all necessary elements for rapid callus formation within the wound itself:* an active periosteum, stimulated by the bleeding, enclosing adherent and free bone fragments which are almost comparable to grafted bone, marrow scattered all round the shaft and amongst the muscles and deep cellular tissue, ready to take part in bone formation. In a few days a resistant enclosing belt is formed, within the protection of which the normal processes of repair can continue, as in a simple fracture.

Union is often singularly rapid; I have seen a fractured femur unite in twenty-five days; but the callus is not yet firm at this stage, and can generally be broken down by hand under an anæsthetic. Slowly and little by little its substance becomes definitely organised until the formation of the original bone is reproduced.

Unfortunately such aseptic development is a very

rare exception, occurring only in fractures by bullets which have produced only punctiform skin-wounds. *In other fractures, infection is the rule, and uninterrupted progress with asepsis an exception which should never be relied on, although it sometimes occurs.* For practical purposes it should be assumed that such simple and ideal development never occurs in fractures by fragments of shell, bomb, torpedo or short-range bullets: *war-fractures are almost always infected at the outset.*

Now, without referring to other risks which it involves, infection seriously interferes with the normal progress of union: it is a very frequent cause of pathological callus.

Neither is a united fracture necessarily a cured fracture.

The cure of a fracture requires union by healthy callus with the fragments of the shaft *in line with the normal axis of the limb, so that forces brought to bear on the arm of the lever may produce the usual results, and the physiology of the limb not be affected.* If displacement is not corrected, and the union is anatomically faulty, there is every likelihood that it will be physiologically faulty also, and the word cure in its true sense can hardly be used.

In other words, war-fractures which possess all the elements necessary for prompt recovery, possess too the potentialities of a vicious pathological or faulty union. It is essential to a cure to have an exact understanding of the causes of these pathological developments. Only such knowledge can direct treatment which consistently results in that ideal cure, the only result which repays a systematic endeavour.

III. Pathological changes in a Fracture

1. **Infection and its results.** — Infection interferes with normal progress by modifying the activity of

osteogenetic tissue, exciting, killing, or inhibiting it. The majority of bad unions result from this. Mechanical factors are much less important.

A. Causes and conditions of Infection.—In practice infection always comes from the outside: it enters with the missile and anything carried in by the latter. Doubtless the condition of the skin is not theoretically without its effect, and it would be absurd to deny the importance of prolonged contact between a fresh wound and the ground or dirty clothing, particularly in wet weather. But these are only secondary causes of sepsis: the spread of infection begins deep, when the skin and subcutaneous tissues are still healthy; it arises below the outer muscular layer, in the spot where the shell-fragment is lodged, with shreds of clothing and pieces of stone and wood which it has carried with it.

Much research during the war has shown that bacterial activity begins around the pieces of clothing between the ninth and tenth hour (Policard). There is nothing on the surface for some time. The point is therefore proved.

Bacteria concerned.—The first organisms to multiply are the vibrion septique and B. perfringens (*Aerogenes capsulatus*); between the sixteenth and twenty-fourth hours the streptococci, staphylococci, and pneumococci appear, and thenceforward the flora of any wound remain very complex. In a general way it may be said that any wound is infected in every possible way at the outset, although nothing of this can be determined at that stage.

Factors controlling the seriousness of an infection.—Though all fractures are generally infected in much the same way, the results are not always the same. Numerous factors influence the infecting organisms, increasing or modifying their virulence: great variations exist in every group of bacteria, and certain factors which Wright has described may intervene *in*

situ. In practice, from the surgical point of view, and particularly in the case of shaft fractures, there are only two definite factors which determine the seriousness of the infection—the *extent of muscular destruction*, and the *existence of anatomical conditions producing complete enclosure*.

Destruction of muscles is a constant feature in the region of the injury, but it varies in extent. Sometimes it is confined to the immediate neighbourhood of the missile's track, and muscles in contact with the bone are uninjured. In any case, and more usually, the injury to muscles is considerable, out of all proportion to the size of the shell-fragment : at a great distance from the seat of the fracture and the track of the missile, muscles are split and destroyed, and vessels are thrombosed ; œdematous infiltration of the periosteum is found where it is least expected. There is wild and indiscriminate destruction, muscle being devitalised so as to produce a perfect medium for bacterial growth. Immediately surrounding the fracture there is little else but muscular débris, and it is in the region of this ready-made incubating area, strewn with foreign débris and shreds of clothing, that the infection develops.

The essential gravity of these cases will be understood, particularly where the track is very oblique and the damage to muscle is consequently very extensive.

These features are most marked in certain regions, the thigh, the neighbourhood of the triceps brachialis, the antero-lateral compartment of the leg, and wherever tough fasciæ completely enclose the muscular bellies. On the other hand, where there is no muscle, the development of severe sepsis is unusual.

Other factors, however, influence the course of the infection.

In fractures of superficial bones, with a widely open wound, the infection is not a serious matter, even if

soil and pieces of clothing are in contact with the broken bones. On the other hand, it is very serious when a deeply seated bone is buried in powerful muscles which enclose the region of the fracture, and where the latter is closely and firmly surrounded to the exclusion of air and light. In other words, the worst infections develop where a completely enclosed area is produced. This fundamental proposition is a clinical fact which it would be idle to substantiate; it is not original; the classical term "débridement," which describes the essential process of war surgery, in itself proves how old this clinical axiom is.

Again, this enclosed area favourable to sepsis is quickly reinforced by it: from the earliest stages of protective reaction, even before infection has begun to develop, the rigidity of the injured area increases, the swollen and œdematous muscle closing more completely than ever the region of osseous and muscular destruction, which becomes a perfect incubator: to the favourable anatomical conditions of enclosure, pathological conditions are added, and the development becomes still more rapid, and hourly more formidable and dangerous.

B. Results of Infection.—If clearance and exposure of the region are not rapidly effected, sepsis produces most serious anatomical and clinical results; sometimes death ensues so rapidly that the spread of sepsis has hardly time to develop and its anatomical results are negligible; more frequently things are otherwise, and the local effects of sepsis control the clinical progress of the fracture.

I shall divide these results into three main classes:—

1. *Septicæmia.*—Theoretically, the rapid development of infection in a wound presenting a large absorbing surface may be followed by acute septicæmia. In practice it is very rare, and septicæmia is not encountered. So far, it has scarcely been proved by bacteriological methods: blood-cultures, though frequently

made, have very rarely given any results, except in the last moments of life, and clinically, rapid deaths, sometimes attributed to very severe septicæmia, are much more probably caused by the absorption of toxic products of muscular necrosis which plays so important a part in influencing the earlier symptoms.

The proof of this is that thorough cleansing of the area and the surgical removal of all devitalised tissue (the latter augmenting the absorbent surface and poisoning effect) abolish all evidence and likelihood of toxæmia, after which secondary visceral lesions, such as would certainly appear had there been a general infection from the outset, are never seen.

2. *Gas gangrene.*—This is the most formidable and common infection which develops in fractured areas. It is not usually a septicæmia ; in spite of the gravity of the general symptoms the initial lesion is definitely localised. So large a number of bacteriological and clinical forms have been described that it is difficult to know where one is. In my opinion, it is the anatomical localisation of the primary focus of infection, and not any specific form of organism, that really determines the clinical form of the affection ; phlegmonous erysipelas, diffuse gaseous cellulitis, or true gas gangrene arise according as the infection is cutaneous, subcutaneous, or deep in the muscles. In fractures the deep form is usually found, that is to say, true gas gangrene, rapidly progressing and soon complete.

The fracture itself is not responsible for this ; it is the muscular injuries in an enclosed area which are the primary factor in the infective development. Injured bone plays no part except in augmenting muscular injury (laceration by scattered splinters), and in contributing to produce necessary local conditions by detaching muscles from their insertions.

Gas gangrene is not a mysterious phenomenon whose pernicious effects are not to be escaped from : it should be regarded as a gangrene, chiefly mechanical in origin

resulting from interference with the blood-supply, of otherwise healthy muscular tissue, this effect being due to the pressure of gas produced by histolytic organisms in a closed muscular wound,* or by the disintegration of muscle. Amongst the organisms found in such an injury, a certain number, or at least B. aerogenes capsulatus, are capable of producing gas, and it appears that the disintegration of muscle favours this process. The gases in themselves are not poisonous ; their pressure is merely evidence of bacterial activity. If the wound is closed, it cannot escape, and spreads into the sheaths of the muscles surrounding its incubating chamber. The distension which follows closes the deep wound even more firmly, and blocks every way of escape ; the pressure increases fatally ; capillaries are compressed, and the circulation, even in parts which are still unaffected, is stopped, and in this way an acute gangrene is mechanically produced in the infected area.

Owing to the fascicular arrangement of the muscles, the progress of the gas continues, causing extension of the gangrene, whose products of decomposition are absorbed, causing serious toxæmia which presents the clinical features of septicæmia.

There may be other forms of gaseous infection, but I believe that true gas gangrene complicating fractures is almost always a gangrene produced mechanically by impaired circulation, gas under pressure directly causing obliteration of capillaries and producing gangrene which results in death from toxæmia.

In brief, gas gangrene, or rather gangrene caused by gas, is a purely local complication of the infection of muscular wounds accompanying fractures. And local treatment, if sufficiently comprehensive to clear out the area of muscular destruction including the closed

* The bacteriological researches of Kenneth Taylor confirm at all points the theories developed here of the mode of action of gas gangrene.

cavity, is always sufficient prevention, should signs of the infection appear early.

3. *Osteomyelitis and its results : the pathology of the Callus.*—Infection of the bone is the most characteristic complication in fractures which have escaped the formidable consequences of muscular infection in a closed cavity (gangrene caused by gas).

Direct infection of the seat of the fracture and of the bone-marrow is a constant feature of all fractures where asepsis has not been ensured by operative interference. Bacteria find the conditions here the more favourable since there are more clots, muscular débris and fine bone particles in contact with the shell fragments and scraps of clothing, since large splinters surround the area, since more fissures exist, and finally since the wound is less directly open to the exterior.

At any rate, the ends of the bone, bruised, and affected by traumatic osteitis, as the older writers called it, rapidly become infected ; suppuration begins on their surface, at first slight, but later more and more profuse, the first result of which is to precipitate the necrosis of any parts whose vitality is diminished, the structures thus necrosed further helping to increase suppuration.

(*a*) *Free fragments*, which in a clean wound would have been so many active grafts, rapidly become sequestra which suppuration tends to eliminate.

Partly detached splinters, which only retain slight vascular connections with bone and muscles, lose these by thrombosis of their vessels, and become so many fresh sequestra whose presence stimulates infection and largely augments pus-formation. This spreads along the extremities of the shaft, and a regular vicious circle is introduced, suppuration increasing in order to eliminate débris the necrosis of which it has itself produced.

Firmly adherent splinters, whose vitality at first appeared sufficient, rapidly become diseased under the

influence of sepsis; the infection spreads along the fissures bounding them, involving them in a continuous layer of leucocytes, which soon develop into fleshy granulations; their presence obstructs vessels and displaces the fragments, to such an extent that soon they are nothing more than fragments of inflamed bone; they are rough to the touch, with periosteal new deposits on their surfaces, not dead white like traumatic sequestra, but showing red patches as in sequestra from osteitis; these splinters slowly die.

It is true that this is not always so; there are many adherent splinters which resist infection and become incorporated in the callus, but the reverse is much more common. In all fractures which have been insufficiently cleared out, and have suppurated for any length of time, osteitis in the adherent fragments is the rule. The majority work out sooner or later; the others remain diseased, and cause the persistence of sinuses, with considerable pain at the level of the fracture. Apart from fractures by shrapnel, and a few favourable cases by shell-fragments, it could almost be said that the only difference between free and adherent splinters lies in the length of time elapsing before they make their way out. In any case there are numbers of wounded at the bases who collect in a box the splinters which their medical officer has carefully preserved, and which have come to the surface in the pus. Exaggeration, however, must be avoided. The one important fact to remember is that in septic wounds which are not speedily cleansed, few splinters escape osteitis.

Sepsis has also a deleterious effect on all the constituents of the broken shaft.

(*b*) *The bone-marrow*, biologically the most delicate of them, is the first to be affected and killed; it is invariably affected to some extent.

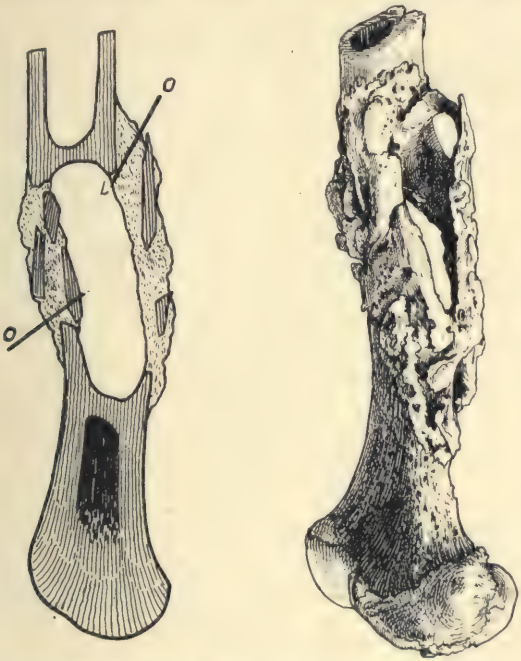
During the early stages of less serious cases, this is evidenced by the formation of a purplish protrusion

blocking the medullary canal; this plug does not bleed, and is easily displaced by the finger, leaving a marked hollow space in the canal. This is seen well in X-ray photographs; the medullary cavity above and below the fractured area is apparently empty, seeming more translucent than the rest of the bone.

When the sepsis is more marked, medullary infection spreads much further, sometimes traversing the whole length of the shaft, even reaching the epiphysis; infection of the joint sometimes occurs along some unusual track.

Later the disease and death of the marrow are evidenced by the formation of more or less considerable sequestra from the ends of the shaft. It occurs in this way: where the medullary plug is formed the vessels are obliterated, some of them supply the compact bone surrounding the medullary canal and the destruction of these vessels leads to necrosis of the whole circumference of the bone. On examination, a sequestrum is found in the form of a regularly serrated ring; the projections are formed at the expense of the bone enclosing the medullary cavity in the whole of its circumference. Later this sequestrum breaks up into numerous jagged and irregular pieces which have no characteristic appearance. This *formation of pseudo-fragments as a result of osteitis of the ends of the shaft* should be well understood. The fragments are not traumatic splinters, but sequestra produced by medullary infection, or osteomyelitis in the true sense of the term. They work out gradually if the callus has not already formed, and sometimes the osteitis disappears, but much more often, when the infection of the bone marrow is more serious and extensive, the results are entirely different; the marrow being destroyed for a great distance, a more or less extensive cavity remains in the centre of the embryonic callus, which is not filled up by anything, and the periosteum, still adherent to splinters displaced by the injury, forms

a callus outside the long axis of the shaft. During this time the marrow, proliferating outside the area of medullary destruction, forms a plug of condensing osteitis which entirely shuts off the medullary



FIGS. 8 and 9.—Sketch of a femur amputated after the fracture, which had not been subjected to sub-periosteal esquillectomy, and had suppurated for nine months. It will be noticed that the callus extends beyond the shaft (*i.e.* is wider), that it surrounds a hollow cavity, and that ossification occurring round adherent splinters has left an infected cavity whose obliteration is impossible. In the diagram the medullary canal is seen to be closed at each end, and there are two openings (o). After nine months, suppurative arthritis developed in the knee-joint.

canal. Thenceforward the cavity is closed and bounded by rigid and inextensible walls, a condition which is intrinsically incurable, none of the walls

being able to come into contact with one another. At each end of this cavity, in which infection persists, the diseased ends of the shaft continue to produce inflammatory sequestra, whose presence promotes continued suppuration.

Cases are thus seen with a large callus completely surrounding a closed infected area, with no outlet to the exterior except sinuses which cannot be cleansed.

Sometimes closure of the external wound occurs after removal or elimination of a sequestrum, but a fresh sinus soon develops, showing that another sequestrum has formed and, being imprisoned, tries to escape.

The track of a fistula through the soft parts is hard and lardaceous, and its walls are not elastic. Outside, round the external opening, the skin is purplish and shining. There is a tendency for cicatrisation to spread up the opening, and sometimes actual tunnels of epidermis, 2½ inches in length, are removed, but cure is still far distant, such cases being doomed to a succession of operative interferences without any guarantee of a satisfactory ultimate recovery.

This is a course frequently taken by disease of the bone-marrow, but it is not the only course.

Sometimes when the medullary canal has been exposed by the missile (and particularly, I have found, when the continuity of the shaft has not been broken), a condensing osteitis appears which thickens the bone enormously and tends to obliterate the medullary canal, the bone becoming as dense as in a case of rickets. This large ivory-like mass is often the seat of a peripheral osteitis; eroding abscesses are formed which can be cured by small incisions, leaving a limb riddled with scars, with stiff sclerosed muscles, hardened fasciæ, and thrombosis in many of the smaller vessels.

X-rays show a compact mass, in which no structural details are visible. This is seen in the femur and

tibia; at least I have not seen it elsewhere. Its pathological anatomy is best studied in the tibia; here condensing osteitis, causing hypertrophy of the bone, mechanically prevents the healing of the stiff and lardaceous surrounding parts. Deep grooves must be gouged in the dense bone, great quantities being removed before there is even a chance of healing. These bones, recalling those seen in long-standing osteomyelitis, are sometimes found after being gouged out to enclose a metallic fragment in the centre of the mass.

(*c*) *The periosteum* is more resistant to infection than the bone-marrow. A small part of it at the ends of the shaft undergoes necrosis, baring the ends of bone in the wound. This is of no great importance unless the marrow is also destroyed, but should it be so, the periosteal infection facilitates the formation of the ring sequestrum of medullary origin described above.

As a rule the infection which destroys the marrow-cells stimulates periosteal activity. But the normal physiological activity of the bone-forming tissue is disorganised, and large masses of unhealthy bone are formed; the normal position of the active periosteum being upset by splintering, it forms a misshapen callus, which, as we have seen, frequently surrounds a totally empty medullary cavity. This is the true classical external callus abnormally developed. Nothing will replace it, since no ossification from within (*i.e.* from the marrow) is possible. Hence the appearance of all the large calluses—multilocular with a central cavity—which are so frequently seen. Inside this cavity there are soft granulations, sometimes fragments of metal, often a bell-shaped sequestrum which is merely a splinter pushed into the medullary canal at the time of the injury, which suppuration has not been able to eliminate. Later on there are sequestra produced by osteitis from the ends of the shaft.

Briefly, in these cases sepsis results in destruction of the marrow and disease of the periosteum the effects of which it will be very difficult to remedy later.

Sometimes a severer or more lasting infection succeeds in inhibiting all activity of the periosteal bone-

FIG. 10.—Typical medullary cavity with a large periosteal callus after union of a shell-fragment fracture which had not been cleared by operation. The sinus persisted for sixteen months, although scraped clear on three occasions. The case was cured by esquillectomy with levelling of the bony walls.

FIG. 11.—Multilocular and multifistular callus (with four centres of suppuration) photographed after seven months' suppuration. All the splinters had been deliberately left to aid bone-formation. Resection of the callus followed by osteosynthesis gave good results, but marked shortening.

forming tissue, just as it has destroyed that of the marrow; after the spontaneous elimination of sequestra, nothing is left between the rarefied and atrophied

ends of the shaft but soft tissue of no definite structure. The death of the osteogenetic cells, without any interposition of muscle between the bone ends or without esquillectomy, eventually produces a definite pseudarthrosis which is extremely difficult to

FIG. 12.—Callus with a large cavity beneath the periosteal bone, in which are recurring sequestra caused by osteitis of the shaft. The case, in which subperiosteal esquillectomy had not been practised, recovered at the end of eighteen months after six operations with ankylosis of the shoulder due to suppurative arthritis.

FIG. 13.—Spontaneous pseudarthrosis after profuse suppuration and the elimination of many sequestra. No operation on the bone had been performed. Cure was obtained by metallic osteo-synthesis. The persistence of displaced sequestra will be noticed in this photograph.

cure, since all power of local bone-formation is lost. Numerous examples are seen in all the long bones except the femur. Almost all the false joints upon which I have operated were caused in this way.

To recapitulate,—*infection is fatal to the vitality of bone-fragments and bone-forming tissue; it destroys the marrow, and inhibits or seriously interferes with periosteal activity; it produces misshapen callus, osteomyelitis, and pseudarthrosis. It is to be feared above everything else.*

Besides these deplorable local effects, infection produces effects equally serious in the bone itself at some distance from the fracture, owing to the frequent existence of *fissures*.

These fissures, unimportant in an aseptic or immediately disinfected wound, seriously affect the prognosis should any suppuration set in. The infection spreads along the fissures to a great distance from the fracture, inducing diffuse osteomyelitis of the shaft or sub-chondral articular osteitis which soon affects the joint and results in serious infection of the latter. In this way suppurative arthritis appears after about ten days in cases of sub-epiphyseal fracture of the upper part of the humerus, or suppurative arthritis of the knee-joint after supra-condylar fracture of the femur; this arthritis necessitates secondary amputations which are not always successful in saving life.

Some of these fissures are visible under *X*-rays, but more usually they are not distinguishable in the negative, particularly in the epiphyses. Some quite extensive fissures are imperceptible on direct examination, and are only recognised in a transverse section of the bone. This explains the possibility of late secondary arthritis after the ankle has been brought to a right angle under an anæsthetic, for instance. In any case, the frequency of these grave complications necessitates thorough operative disinfection of the main fractured area if they are to be avoided.

Infection may reach *joints* in other ways: in very virulent infections, when no fissures exist, suppurative arthritis sometimes develops rapidly; the medullary canal is full of pus; a widespread diffuse osteomyelitis

has supervened, and the prognosis is extremely grave. In section one can clearly see the track along which infection has spread through the cancellous tissue, generally from a splinter within the canal.

Spread of infection may also occur along the compact bone beneath the periosteum, but this is much less common.

Infection is not merely dangerous to bone elements; persistent suppuration has serious effects on the surrounding soft tissues. Tracks of pus develop along muscles, infiltrate muscular sheaths, necrose tendons and fasciæ, and often find outlet at a great distance from the wound. Sclerosis of muscles and thickening of fasciæ follow, the final result always being marked diminution of the functional value of the limb. This is particularly deplorable in the neighbourhood of joints, as stiffness follows, with ligamentous shortening which it is difficult to remedy later.

When suppuration is set up in the neighbourhood of *large vessels*, it is not a question of remote risk, but immediate serious complications may occur. Vessels are undoubtedly very resistant to suppuration round them. It is commonly believed that arteries may be found crossing a large purulent area like a cord, and remaining intact. But this can only occur if an artery is absolutely healthy. If the projectile in passing, or any splinters which it has scattered, happen to injure the artery, sudden secondary hæmorrhage may occur later. The bruised patch, which would have healed easily in aseptic surroundings, gradually undergoes necrosis, and this ulcerated patch is suddenly forced out, causing violent hæmorrhage. The presence of splinters in contact with a vessel, as seen notably in the thigh, facilitates the occurrence of this complication.

Sepsis has little effect on *nerves*, unless they are involved in the original injury. But as in the case of arteries, if a nerve has once been crushed or severed,

and its two ends are in contact with a purulent area for a considerable length of time, healing of the injury is an extremely difficult matter. Hard and dense tissue forms round it which prevents spontaneous regeneration and greatly impedes surgical interference.

2. **Faulty Union** (anatomical and physiological).—Consolidation may be seriously impeded or even actually arrested by certain anatomical causes, the persistence of which usually results in a vicious union.

FIG. 14.—Pseudarthrosis of the humerus due to failure in reduction.

War fractures undoubtedly undergo less marked displacement than those seen in civil life, since the lacerated muscles pull less strongly on the fragments, but there are certain constant displacements where non-reduction entails serious results. Persistent infection with suppuration in the region of the fracture render the latter liable to incomplete reduction, both at first because œdema and swelling of the injured limb prevent its being set easily, and later because the frequent dressing of it for months necessitated by suppuration, render it difficult to maintain absolute immobility.

Callus formation is hindered by *antero-posterior displacement* : thus in certain fractures of the thigh, the upper fragment tends to tilt forwards, while the lower is pulled backwards : without referring to the various effects of muscular action in such cases, it will be

obvious that the formation of a callus is scarcely encouraged by the persistence of wide separation.

Longitudinal displacement or *over-riding* is a still more awkward matter; it is particularly frequent in the thigh and arm. Unless it is reduced, union can only occur by the formation of a lateral periosteal bridge, producing a bayonet-shaped callus which alters the axis of the limb and leads to marked shortening.

Lateral displacement occurs particularly in the neighbourhood of epiphyses and in fractures near joints, frequently giving rise to pseudarthrosis, notably in the humerus and femur: at the shoulder and in the sub-trochanteric region, the upper fragment is maintained in a position of marked abduction by the external rotators inserted in it (connecting the scapula and tuberosities in one case, and the pelvis and the trochanter in the other), while the lower fragment is pulled inwards and upwards by the adductors and internal rotators; approximation of the two fragments is impossible. It is absolutely essential for satisfactory consolidation to bring the lower fragment, the only movable of the

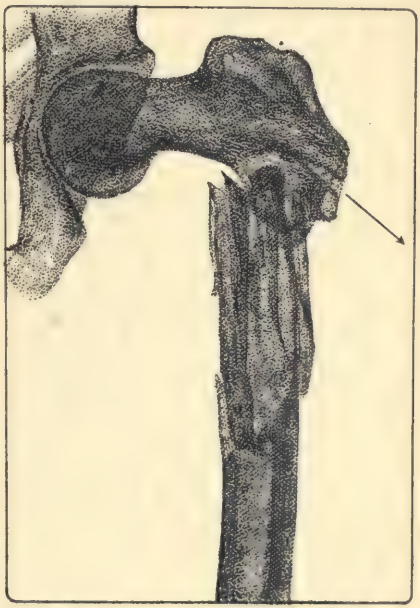


FIG. 15.—Pseudarthrosis of the femur due to failure in reduction.

two, into line with the other; unless this precaution is taken, pseudarthrosis is favoured, and if union occurs, it does so in a faulty position which interferes with the functions of the limb.

Displacement by rotation is possible in all bones, but it is most frequent and serious in the forearm. The upper fragment assumes a position of supination under the action of the biceps and supinator brevis, while the lower is fixed in pronation by gravity and the pronator quadratus. Thenceforward, to use the expression brought into general use by Destot, the bones are " décalés " (deprived of support), and the physiology of the hand movements is seriously interfered with.

Displacement in the line of the bone causes angulation of the fragments, and may occur everywhere, but particularly in the forearm and the leg; the V-shaped consolidation which results is particularly unsound, and, in the lower limb perhaps more than elsewhere, gives rise to marked deformity.

In brief, the various displacements possible in a fracture result in interfering with the formation of the callus by separating the fragments, or by allowing one to form in a faulty position which will deprive the limb of a large part of its functional value.

Correct treatment does not consist only in the maintenance of asepsis: *no fracture is really cured unless the fragments are united by a healthy callus in line with the normal axis of the shaft, so that forces acting on the arm of the lever may be exercised normally and have a normal physiological action.*

Treatment which is intended to restore normal conditions should be directed towards this object.

CHAPTER II

GENERAL PRINCIPLES IN THE CONSERVATIVE TREATMENT OF FRACTURES

For reasons already outlined, it follows that in modern war fractures, other than those by bullets with punctiform wounds,* treatment to reproduce original conditions must involve three essential features: *disinfection*, *reduction*, and *immobilisation*, which are necessary for the production of regular union in a straight line by a healthy callus.

But the order in which these three parts of the treatment are taken in hand is not a matter of indifference: it has often been said during the present war that reduction and immobilisation are the main points in treatment, and, if well realised, by reducing the intensity of infection and the difficulty of treating it, limit the scope of the operation required, thereby reducing this to the category of a secondary intervention.

In my opinion *this is a serious clinical mistake*: undoubtedly immobilisation is at the root of all treatment directed against inflammation, and sepsis developing in a fracture is certainly more serious if the fracture is badly reduced or not immobilised. But this is only one side of the question of the causation and treatment of infection in war: the most complete immobility in the world and the speediest reduction will not prevent the development of gas gangrene if the wound is not suitably opened up, nor will it prevent the appearance of acute osteomyelitis, connected with

* I repeat that extensive crushing justifying amputation is not discussed here.

the presence of infected clothing and débris in the medullary canal.

In regarding immobilisation as the salient point in treating fractures caused by shell-fragments, a great risk is run for which nothing can compensate: no reliance should be placed on stereotyped formulæ; it should be realised that the *essential and fundamental process in the treatment of all fractures, on which depend the patient's future, at first his life, subsequently the safety of his limb, and ultimately its functioning power, is early and immediate cleansing: every fracture*, apart from the exceptions above-mentioned, *should be so treated, as early as possible, that its subsequent course may be aseptic*, in order that no infection may inhibit the bone-forming tissues which effect repair.

The other elements of the treatment should follow this and not precede it: their proper function is to control the formation of callus, and to ensure that union follows in a straight line: they are the easier to carry out the more regular the progress of the wound, that is, the earlier, more careful and complete the operative cleaning which has been practised. Reduction and immobilisation are only supplementary to the operation; they should follow, and not precede it.

With this in view, I shall discuss:—

1. The disinfection of fractures by operation.
2. Reduction.
3. Immobilisation.

I. Operative Disinfection of Open Fractures *

This should be considered in two categories:—

In (*a*) the wound is seen in the first few hours,† previous to any clinical sign of infection.

* I use this term once more to exclude bullet fractures with punctiform skin wounds, which should be classed, as I have said, as simple fractures.

† Theoretically this means in the first twelve hours; practically, in the first twenty-four.

In (*b*) the wound is seen after the appearance of symptoms of infection.

A. Initial operative disinfection of fractures in the first few hours : exploratory and prophylactic esquillectomy.

1. The Principle.—Like all war-wounds, fractures should be treated by operation as speedily as possible, in order to ensure complete prevention, at the outset, of any acute or chronic infection which threatens the injured region. There being no means in the earliest stages of distinguishing seriously infected from only slightly infected fractures, all should receive the same preventive treatment without distinction.

This principle of general disinfective action is at the root of all prophylaxis.

It is essential, therefore, in any individual case, as in all wounds of war, at once, *even if not the slightest sign of infection has appeared*, to remove any foreign bodies in the wound, scraps of clothing, tissue destroyed by the injury or liable to necrosis following infection : the wound after such treatment should be clean, containing no suspicious elements or recesses where infection may develop. Everything contused or lacerated should be exposed thoroughly.

The operation required is not a mere matter of drainage (*e.g.* widening the entry and exit wounds to introduce drainage tubes, after a rough cleaning of the soft parts), *nor should it be limited to partial and prudent removal of a few isolated fragments dictated by a groundless fear of pseudarthrosis ; still less should it be a rapid and indiscriminate scraping of the fractured area, bringing out everything that the instrument encounters as it is withdrawn.*

The danger lies in the medullary canal.

This particularly should be laid widely open by a methodical operation consistent with the main principles of preventive disinfection of war-wounds, allowing of

complete exploration of the area, and of any necessary excisions.

With this object, the operation should be conducted in the following way, under a general anæsthetic and after radiography if possible, for the ideal is to approach the fracture with an exact knowledge of its structural details.

A long and carefully placed incision is made, to facilitate, first, the removal with bistoury and forceps of any soft tissues which are contused or crushed; a search is then made for foreign bodies: in brief, nothing should be left in the region of the fracture which will infect it or encourage infection to develop.

This done, all free splinters which have been forced into muscles must be removed with great care. Patient and minute search is required, not a hasty clearance Next, the region of adherent splinters is approached, and such are removed as appear to interfere with exploration and thorough display of the medullary cavity.

At the end of the operation the medullary cavity should present roughly the appearance of a groove in cases of fractures with large splinters, a funnel in fractures with one large short splinter, and entire loss of substance in a many-splintered fracture. In the unusual event of a transverse fracture, where there are no splinters, about ½ inch should be resected from each end of the shaft, as the latter are contused and devitalised by the violence of impact.

Nothing, in fact, about which there is any suspicion, nothing which can favour infection, should be left in the neighbourhood of the fracture, so that infection may not interfere with union, by causing necrosis of the osteogenetic elements in the marrow and periosteum.

2. ADVANTAGES.—*This wide esquillectomy, the sole means of obtaining a detailed knowledge of the injury, is a preventive step, since it removes all unknown factors from the wound.*

(*a*) *It absolutely prevents the development and conse-*

quences of serious sepsis.—If these appear it means that the operation was badly or only partially done. No proof of this is needed beyond the fact that the operation is intended to remove anything calculated to produce sepsis or to favour its development.

All who have performed this operation are unanimous in declaring that it has enabled them to avoid gas gangrene and acute osteomyelitis; others who first criticised it have ultimately declared in its favour.

For my own part, I have practised it systematically since the month of August 1914, according to the principles and methods of my teacher, Poncet. I am doing practically the same now as I have done from the beginning, without introducing any new feature. In this way I have been able to cure more than 250 comminuted shaft fractures with the loss of only one case, without a single case of gas gangrene, and with only one case (which proved fatal) in which persistent sepsis necessitated amputation.*

Supplementary proof is easy: at the front the surgeon has only to reckon the number of his secondary amputations for fracture; at the base he has merely to question these men, and he will find that the majority of these amputations were necessitated by fracture, and that in almost every case the amputation was secondary.

It may be said that, in an ambulance unit at the front, the number of secondary amputations is inversely proportional to the number and extent of early esquillectomy operations.

Further, if need be, the question can be decided by studying the development of each surgeon's personal views; the number favouring this operation on principle has become considerable, and each recommends a more and more comprehensive operation. At first, in August 1914 and early in 1915, we were very few

* Esquillectomy was performed on the third day after sepsis had fully developed.

and very much criticised; everything that I have since seen and done has shown me that we were right.

In brief, after twenty-two months of war, it must be acknowledged that wide and early esquillectomy is an absolute protection against the serious infections which endanger the life, or at least the limb, of every case of fracture, and that it *alone* will give this result.

(*b*) But that is not the only advantage of this method: immediate complete esquillectomy, by allowing of complete investigation of the wound, also ensures the prevention of all the slight chronic infections whose secondary effects are so prone to prevent a satisfactory union of the fractured bones. By it all foreign bodies, all tissue débris condemned to necrosis, are removed at once. This avoids the occurrence of that persistent suppuration which, sometimes destroying marrow and periosteum, leads to pseudarthrosis, sometimes, by irritating the periosteum and disturbing its osteogenetic activity, eventually produces a pathological callus, within which infection produces necrosis of the ends of the shaft and causes persistent osteitis.

A radical esquillectomy entirely exposes the medullary canal, which is often filled with small fragments and metallic or other particles; without it, these cannot be removed, and osteomyelitis is certain; sometimes it is acute, sometimes chronic from the beginning. It can only be avoided by completely cleaning the area of destruction in the shaft.

In the large number of shaft fracture cases which I followed until cure, there were only about ten in which a sinus persisted. This always occurred in wounds in which I had thought it well to leave one or two fragments, apparently firmly adherent and well supplied with blood; in these, removal of the fragments stopped the discharge. There were very few amongst my cases in which a late abscess developed (after a year or more), whereas this is usually very frequent; the two or three which I have seen have

appeared in cases upon which I had operated too late to prevent serious sepsis. Anyone who knows the appalling amount of osteitis, osteomyelitis, and cases of persistent sinus which fill our military hospitals at the present time will not for a moment question the enormous advantage of avoiding the terrible consequences of early infection.

3. Criticisms of this Operation.—Free prophylactic esquillectomy is not, however, practised everywhere. Many surgeons are afraid of it, and assert that it predisposes to pseudarthrosis.

(*a*) *It is useless*, they say, *because many fractures unite without such immediate operation if they are properly immobilised*, and because, if it prove necessary, a secondary and limited esquillectomy, not interfering with any adherent fragments, is almost always sufficient. Later, if necessary, the surgeon is free to search for any enclosed sequestrum, but interference should be limited to this, and this is better than a flail-limb after removal of an excessive quantity of bone.

Thus described it seems natural, and even wise, to refrain. But is this a true statement of the case? This supposed harmlessness of war-fractures has scarcely been seen except at the bases, where the question cannot rightly be judged. A man must go to the front to appreciate truly the seriousness of fractures by shell- or bomb-fragments. Now even at the present day, after twenty-two months of war, this is what is to be seen there: wherever free esquillectomy is not carried out early and systematically, before any clinical sign of infection, cases of gas gangrene and serious osteomyelitis have still to be battled with; there are deaths from sepsis, and early secondary amputations for infected fractures. On the other hand, where esquillectomy is a general rule, there is no gas gangrene, and no dangerous sepsis except in cases already developing it on arrival; fracture cases

explored early run an aseptic course, and no secondary amputations for septic fractures are performed.

Early free esquillectomy or frequent secondary amputations—the question can be expressed in no other way—and it is this fact which must be realised by anyone who wishes to get to the root of the matter.

In the base hospitals it is a different matter: unoperated fractures arriving twenty-four or forty-eight hours after evacuation are more often caused by bullet wounds, punctiform at entry and exit (whose habitually aseptic course everyone knows), or by shrapnel bullet (whose comparative benignity is frequent). Unoperated shell-fragment cases are more and more rare, for the simple reason that surgeons at the front, better aware of the serious danger which these cases run, do not send them further until the initial esquillectomy has been performed.

(*b*) *But*, it will be said, *why advocate so sweeping an interference? Why not limit it to the removal of free splinters, leaving those which are adherent and living?* Would it not be better to retain everything which appears likely to live, leaving it to Nature to decide what she wishes to retain and what to reject?

This would obviously be the ideal course if there were not certain disadvantages in relying so much on Nature. These disadvantages are the following:

(i) *Serious infection cannot be prevented except by a complete clearance*, leaving nothing suspicious in the wound, which should be mechanically disinfected throughout. If adherent fragments are left undisturbed, how are scraps of clothing to be discovered, caught on the points of the shaft, embedded firmly in the cancellous tissue of some adherent splinters bordering on the track of the missile? How are those isolated splinters to be removed which have penetrated the medullary canal, and are about to undergo necrosis in an already injured region, thus giving rise to serious osteomyelitis, sometimes to interminable suppuration? Wide clear-

ance will ensure sufficient exploration of the fracture to guarantee satisfactory development and repair.

This is well shown by what is found in the wound during a second operation to complete an originally insufficient esquillectomy; in one in three cases fragments of clothing are still found enclosed in it (see fig. 16).

(ii) *Without esquillectomy, the prevention of chronic infection cannot be depended upon* (and this certainty is essential); a fracture

FIG. 16.—Fracture of the femur after incomplete esquillectomy at the front. On the eighth day, when I first saw the case, suppuration was profuse. I removed the large remaining fragment, leaving the periosteum, thereby discovering and removing a shell-fragment and a fetid mass of clothing material rammed high up the medullary canal, which could not have been discovered without esquillectomy. This was sufficient to stop the suppuration; there was no further pyrexia, and on the thirty-fifth day the patient could raise the thigh.

not entirely cleaned will suppurate; this suppuration, which is almost always difficult to stop, will produce the troublesome effects described above, on the ends of the shaft and on the marrow; this should be avoided at all costs, for *anything is better than chronic osteomyelitis of the callus, which may persist for any length of time.* Not enough thought is given to the life which those suffering from osteomyelitis are fated to lead in the future, with continued pain, sinuses constantly reappearing, necessitating repeated operations which they must

undergo without ever knowing how far away is the promised cure, or whether amputation will not eventually be necessary. Surely it is worth while to take any trouble that will save this long martyrdom.

FIG. 17.—Radiograph showing the presence of fragments in the medullary canal; the wound had suppurated at the front for two months, and amputation had to be performed.

This can easily be done without endangering the future solidity of the bone.

Esquillectomy, which protects from everything giving rise to disease of the callus, if properly carried out, should leave in the wound thus disinfected by mechanical means all the elements necessary for speedy union.

(c) *It is also true that certain surgeons have criticised the method by stating that it predisposes to pseudarthrosis*, but their opinion scarcely deserves credit. With no experience of surgery at the front, they have been appalled by certain very extensive removals of bone practised there, in some cases by the careless and ignorant, in others by more experienced surgeons who refused to amputate an arm for enormous injuries when the nerves and vessels were intact.

Ordinary cases are different, and we may once and for all dismiss that dread of pseudarthrosis which has so often prevented necessary steps from being taken; disregarding deliberate removal of bone to avoid disarticulation or amputation, which should not be considered in this connection, it may be stated dogmatically that *pseudarthrosis seen in base hospitals is almost always the result of prolonged sepsis, and not of too free an esquillectomy.*

Speaking practically and theoretically, pseudarthrosis, in the cases studied here, where the interposition of muscle is extremely rare, can only point to one of two equally bad and equally avoidable things—a mere partial esquillectomy, allowing of an infection which destroyed the bone-forming elements in the region, or a technically faulty clearance, which did not leave the latter in place in the wound which it had cleaned.

Now, free esquillectomy does not mean technically faulty esquillectomy. The only technically faulty one is that which, backed by no physiological idea, tears away the fragments which are to be removed, careless of leaving in the wound the fertile tissue of the bone which alone assures the formation of a regular callus.

This fertile tissue is found only between the fibrous layer of the periosteum and the shaft. Ollier conclusively proved its osteogenetic value; by its action the periosteum manufactures bone, with equal ease whether it be young, or irritated by injury or slight infection; but to leave it in the wound, a sharp rugine must be used to separate it from the dense bone to which it adheres; this is essential.

All surgeons who have experimented under the same conditions as Ollier, all those who, like him, have understood, and searched in the periosteum beneath the fibrous layer for the deeper osteogenetically active layer, have got the experimental and clinical results which he described.

Hence it should theoretically be admitted that thorough sub-periosteal esquillectomy with a sharp rugine leaves in place the bone-forming elements which should be sufficient to re-establish continuity of the bone.

It is so in practice; surgeons taught to respect the periosteum have obtained results during the present war which are the best experimental and clinical proof of Ollier's theories that could be adduced. It is thus proved that the only operation justifiable is one

which preserves in the wound the fertile, as well as the fibrous, periosteum.

A well-executed esquillectomy is not simply one which checks infection; it is actually and only that which, taking the necessary preventive steps, leaves in the wound, undisturbed by any pernicious infection, the periosteal bone-forming elements which will eventually form a regular callus: *only a thoroughly sub-periosteal esquillectomy is justified.*

The question is, then, a simple one: esquillectomy followed by pseudarthrosis is a badly executed esquillectomy. *Early sub-periosteal removal of fragments under ordinary operative conditions does not expose the fracture to the danger of pseudarthrosis, and such an operation is conducive to rapid recovery and is physiologically justified.*

Further, it should be understood that the original esquillectomy is not a resection of the entire circumference of the bone; it is not even a total esquillectomy. The object of clearance at this stage is to display the area clearly and to remove everything which interferes with complete exploration of the injury and with drainage. In more than two-thirds of cases the operation ultimately leaves the ends of the shaft in contact, thinned down but forming an almost continuous trunk, without reducing the total length of the bone.

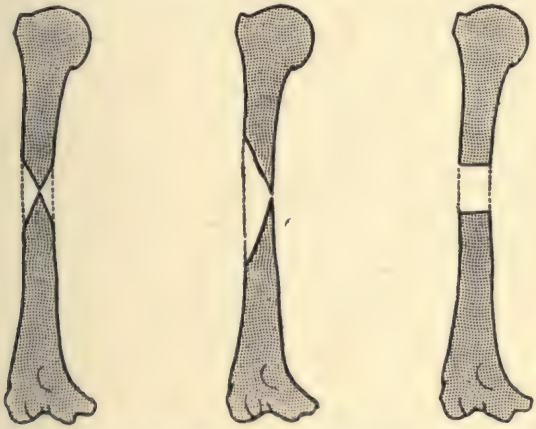
In large-splintered fractures it is indeed sufficient to remove the principal fragment obscuring the medullary cavity. After the operation the continuity of the bone is hardly interrupted. Anyone doubting this has only to think of the classical description of the "butterfly wing" fracture, which is equivalent to this type; removal of the lateral fragments leaves the extremities of the shaft intact, and meeting at the point of impact of the missile.

In fractures with one large and short splinter, it is enough to remove this, detached as it is and wedged

between the ends of the shaft, and still adherent to muscles, together with any smaller fragments of it which are already dead; when the clearance is complete, the shaft has lost nothing in length, but is only deeply notched.

In fact, *in at least two-thirds of the cases, free esquillectomy reduces the thickness and not the length of the bone.*

This being the case, it is illogical to hesitate at esquillectomy; the anatomical arrangement of the ends of



FIGS. 18, 19, and 20.—Diagram showing what is left by esquillectomy adapted to the lesions in different types of fracture. Compare figs. 1, 2, 3, and 4.

the shaft is such that consolidation is possible even after an esquillectomy almost regardless of the periosteum, and cannot fail after an entirely sub-periosteal operation.

There remains the case of *shattering into small splinters*: if the shaft is shattered in its entire circumference, clearance is necessarily total, since scarcely any of the splinters are adherent. In theory, there is some fear of a false joint, but if great care is exercised in preserving scraps of periosteum, if the very

natural desire to remove more or less adherent fragments by a sharp twist or violent pull is resisted, if any remaining periosteum is carefully removed from free splinters with a rugine (such splinters being found on the outskirts of the fracture), a kind of periosteal sheath remains—lacerated, no doubt, but sufficient in its length to ensure the formation of a regular callus.

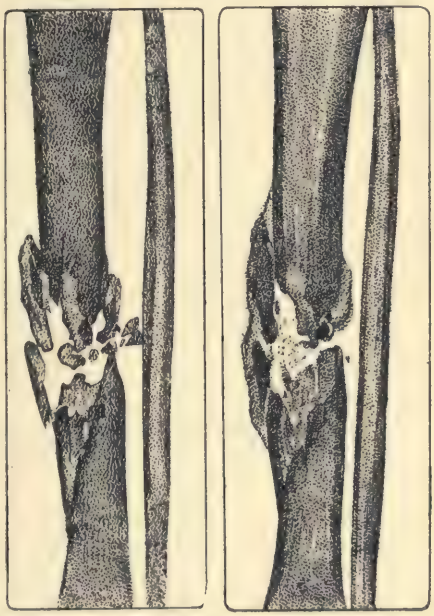
Here the process is decidedly longer than in the preceding cases, but it is equally sure and reliable; the callus which results is equally solid, particularly if no attempt is made entirely to prevent shortening by applying too powerful an extension.

Although in the former cases (the large, long-splintered type and that with one large short splinter) I have seen firm union occur sometimes in 30 days in the forearm, in 35 in the humerus, in 42 in the leg, and in 45 in the thigh, 2 or 3 months elapse when there is extensive shattering: it begins slowly towards the 35th day by the formation of a fibrous, slightly elastic and flexible mass which gradually hardens, generally on one side at first, and eventually becomes a solid and regular callus. Often, moreover, the missile not having struck the shaft squarely, the blow was more or less glancing, and, after removal of small splinters, a projecting piece of the shaft remains.

All possible criticism of removal of fragments is negatived by the arguments I have reiterated here.

But esquillectomy has another very great advantage to which attention has never been drawn, and which is of great interest: *it is the only sure means we possess of moulding the callus at will* in the right direction. When numbers of splinters are left on the borders of the area there is a temptation to use them as supporting arches for ossification. If they happen to remain, bone-formation begins around them—that is to say, to some extent along a different axis from that of the bone itself; the callus, from the way in which it is formed, will be shapeless, irregular, and

redundant; sometimes it will enclose fragments of muscle, and I have twice seen pseudarthrosis produced in this way in the centre of a partially ossified mass. If there is any infection, the marrow will die and disappear, and no bone-forming tissue will be there to fill the central cavity; thenceforward an infected cavity will persist in the centre of the bone, the cure of which will be difficult if not impossible. If, on the other hand, all fragments of bone forced out and displaced by the injury are removed, and one side only of the shaft is allowed to remain, the periosteum will be grouped by muscular pressure round the grooved bar remaining, and the callus will form along this in the shape of a regular solid column, with no gap or infected cavity: bone-formation is, as it were, guided, and the callus thus produced will give infinitely more security for the future than one built around diseased, dead, or displaced fragments.



FIGS. 21 and 22.—These two radiographs, taken at three months' interval, show well how fragments left in place cause an outward bulging of the periosteum, and how, owing to this, a central cavity is formed within the callus. Compare fig. 10.

Decidedly, instead of hesitating at wide preventive

esquillectomy, the surgeon should regard it as the ideal operation for fractures, since, while entirely protecting the bone-forming tissues from damage by infection, it ensures the formation of a healthy callus in a regular way—a callus enclosing no undesirable foreign body, nor threatening any subsequent formation of fistulæ.

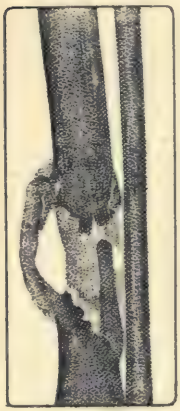


FIG. 23.—Bridge of periosteal callus formed along an adherent fragment in the lower third of the tibia; the splinter, which occasioned a fistula, had to be removed; the protruding callus ulcerated the skin of the leg, and had to be removed later in order to bring about healing.

B. Secondary operative disinfection of clinically infected fractures: Esquillectomy and drainage: total sub-periosteal esquillectomy.

The reasons for regarding wide sub-periosteal esquillectomy as the preventive operation *par excellence*, should, for stronger reasons, bring it to be regarded as the only form of intervention ensuring the disinfection of recently infected fractures. It is a typical drainage operation, since it completely exposes the injured area, and abolishes everything which could facilitate the development of infection, *i.e.* the closed cavity, unhealthy débris, and tissue of diminished vitality.

Practically, it rules out all serious sepsis, rapidly removes less serious infection which is tending to become chronic, and quickly abolishes all infections which cannot develop in the presence of air: it thus assures the regular formation of a healthy, and in no way pathological, callus. This callus is not an outer shell enclosing an empty central cavity, but a compact, connecting column, in one piece, having nothing in common with the misshapen callus produced by a diseased periosteum round an infected medullary cavity.

No other operation can fulfil these purposes; if any fragments of diminished vitality, around which infection may, and often does, develop, are left in a fracture, the operation is not one to be relied on to give

FIG. 24.—Copy of a radiograph made after secondary supplementary esquillectomy on the thirteenth day for fracture of the thigh. A large adherent splinter left in place was removed, as were two pieces of shell, one of which was in the medullary canal. The suppuration stopped at once without the use of an antiseptic.

FIG. 25.—Sketch showing the callus obtained in sixty days. Union had occurred forty-eight days after the operation. The patient could walk on the sixty-second day.

an invariable and sure result.

It is not a matter of *mere drainage of the soft parts*. The pathological physiology of infections forbids any thought of that.

Partial and prudent esquillectomy, *i.e.* a hesitating

and incomplete operation, is fatal in leaving the principal infected area untouched: it deliberately avoids the root of the trouble, and permits neither a thorough search for fragments of metal and clothing nor an exploration of the medullary canal, which is absolutely necessary. It limits itself to a little tentative draining, and is often carried no further than this; sooner or later amputation is necessary in cases which this method has proved incapable of curing. It is easily judged to-day by its results; it has peopled our towns with men who have lost limbs and has filled the hospitals with unfortunate men whose wounds have been suppurating for months, almost for years, still possessing incurable sinuses in spite of all treatment.

FIG. 26.—Radiograph of a callus in the ulna, six months after total secondary esquillectomy. Compare figs. 95, 96, 97, 98, which illustrate the same case.

The anatomical and pathological conditions of an infected fracture are such that any intervention which does not establish drainage of the medullary canal and removal of all débris about to undergo necrosis is a bad operation. Theoretically this is so; it is also true in practice.

Blind and partial operations should therefore be dismissed.

On the other hand, wide esquillectomy which allows of thorough exploration of the wound, removes necrosed, infected, or infectable tissue débris, and, having thus displayed the wound well, leaves in it only elements necessary for repair, and at once and invariably ensures automatic disinfection and drainage; it does for the infected shaft-fracture what sub-periosteal resection will do for an epiphyseal fracture.

It should, therefore, be employed at once and systematically in all fractures whose course is not clinically aseptic.

What has been said of periosteal bone-formation after sub-periosteal esquillectomy, and the X-ray photographs which will be found in the book, will suffice, I believe, to show that the method does not tend to produce pseudarthrosis.

Briefly, *wide sub-periosteal esquillectomy is the only logical operation in harmony with present-day anatomico-pathological theories on the development of septic fractures in warfare.*

No other permits complete exploration of the region concerned, and treatment of the injuries caused by the missile after thorough exposure of the wounds to the air. Owing to the exploration, prevention of infection, and drainage which it includes, this method alone consistently achieves continued asepsis of the fracture. Thus it ensures the normal production of a healthy callus from the bone-forming tissues which it has preserved in the wound. These, restored by the rugine to their position in relation to the shaft, will develop a regular osseous column in line with the shaft, without the empty central cavity which is so favourable a seat for chronic infections.

C. General indications for the operation.

1. As a preventive of infection.—Sub-periosteal esquillectomy should be carried out as early and promptly as possible *in all fractures caused by fragments of shell, bomb, or torpedo, or by bullets with accompanying explosive effects.* In all these cases no clinical sign of infection should be waited for before operating. As in all penetrating wounds of the abdomen or joints, an exploratory transosseous operation is absolutely necessary. Apart from tracheotomy or the ligature of a large vessel, no class of case calls more urgently for intervention than this: in the ambulance, the exploration of limb fractures should be carried out

immediately; if it is a matter of choosing between several cases, some of which will be obliged to wait, *fractures should receive attention first.*

In the event of a rush, the surgeon at the front is strictly bound to deal with the greater number, and with those whose life he is most certain of saving, and whose condition he is best able to improve. He is under a definite obligation to operate on fractures rather than abdominal cases should they arrive simultaneously, unless he is certain of being able to deal with all within a limited time: twenty esquillectomies are worth more than ten laparotomies, the definite gain from the humane point of view being greater.

It goes without saying that these rules are irrelevant to periods of relative quietness, when there is time for everything.

But what should be done in the case of shock?

Many cases of fracture, particularly those of the thigh, are in a condition of severe shock. Should the operation be postponed until the next day? Are these cases in too critical a condition for a general anæsthetic and a necessarily rather long operation? A careful esquillectomy requires half to three-quarters of an hour: is this not too much for men who are faint and chilled?

Yet complications may be imminent. A case exhibiting severe shock is sometimes threatened by serious infection, and will not survive unless an immediate operation is performed.

Theoretically the question appears insoluble; practically, it is a matter of judgment. A case exhibiting severe shock will not be transferred direct from the stretcher to the operating-table; the first step is to treat the shock. The patient is placed in bed in the horizontal position with the head low, and is warmed, and ·01 grm. morphine is immediately given: morphine acts marvellously in the majority of cases, apparently counteracting the peripheral vaso-

constriction. By a reverse process a similar effect may be attempted, by endeavouring to induce contraction of the abdominal vessels in order to restore the quantity of blood contained in them to the general circulation : this justifies the use of emetine (·05 to ·1 grm), or of pituitrine : this method is superior to the injection of quantities of saline, which perhaps often has an effect opposite to that desired. On the other hand, small doses (150–200 grm.) of very warm saline containing adrenalin, injected intravenously, and repeated every two hours, give excellent results.

After five or six hours the operation is performed. It should not be delayed longer ; shock which resists the above treatment has a permanent cause in the region of the wound which must be removed at once. Some of these operation cases will die, but experience shows that in these fatal cases, shock persists until death, and nothing would have been gained by waiting. Others recover without difficulty.

Is it possible to distinguish between these cases ?

Clinically not, but Sencert has shown that the height of the blood-pressure gives definite information : there is a minimum pressure, and should the patient's fall lower than this, there is every likelihood that he will succumb rapidly. All cases which Sencert has seen, whose blood-pressure before the operation, measured by Vaquès' apparatus, was below 10, died ; the rest recovered. Apart from this excellent procedure, there is no definite anti-operative indication.

In the absence of shock, should all fractures be treated by *immediate* operation ? Yes, all *fractures by fragments of shell, bomb, or torpedo, or by bullet with accompanying explosive effects.*

In fractures by shrapnel balls, shown by X-rays to be such, a few hours' delay is theoretically justified, if time is plentiful, to decide whether an operation shall be performed. Infection is less constant in these cases than in fractures by a shell-fragment. Arrange-

ments, however, should be made for the case being watched closely, for there are a number of these fractures whose course is identical with that of the worst shell-fragment fractures (those in which the bullet, originally spherical, but more or less deformed on impact, has carried in fragments of clothing with it). If, therefore, there is a large influx of wounded, there should be no delay; the fracture, though perhaps benign, is treated like the rest, rather than risk death from sepsis, or an amputation, in a case which originally appeared the least serious of all.

In practice, I think it better to make no distinction between fractures by shrapnel balls and others; the fundamental rule of prevention holds here as elsewhere, and it is better to perform the operation in nine cases not requiring it than to lose a single life by refraining from it. It is, moreover, certain that the nine operations will not prove to have been useless.

In bullet fractures with small skin wounds, but larger than the punctiform type, clinical signs should be awaited, and treatment limited to immobilisation. Infection is not usually fatal; it is often benign, and the patient can be evacuated forthwith. But if the wound of exit exceeds one inch in breadth, immediate preventive intervention is required, since serious infection is usual in this case.

2. As an operation for drainage.—Sub-periosteal esquillectomy should be done at once in all clinically infected fractures, and in any seen after twenty-four hours or later. It should be practised even if there has been an earlier intervention, should the case present signs of increasing infection, or if the wound is suppurating after an interval of several days. This is frequently seen at base hospitals. In fact, the majority of cases sent back from the front are suppurating to some extent, in spite of various antiseptic dressings. These wounds appear clean, but they are never aseptic; the infection is slight, but it

is nevertheless an infection, and this should not be so. Suppuration after five, six, or eight days, and particularly after a longer time than this, is indisputable proof that the original cleaning was incomplete, and that there are still fragments of bone and gangrenous tissue to be removed which have been left in the wound, involuntarily or not: to speak plainly, the operations in these cases have been incomplete.

In fourteen shaft fractures arriving in fifteen days during an offensive, I found under X-rays splinters undergoing necrosis in fourteen cases, and in all the cases I operated to remove them. In eleven cases careful and methodical sub-periosteal esquillectomy, ethyl chloride being used as an anæsthetic, was sufficient to arrest suppuration and *enable the injury to take a clinically aseptic course.*

This result could have been obtained at the outset. In five cases adherent splinters were removed in which were engaged fragments of clothing whose spontaneous elimination appeared impossible. In three cases successive operations were required for the draining of abscesses, and an aseptic condition of the wound was only obtained at the end of a fortnight.

It will perhaps be said that this secondary cleaning was, to say the least, useless, and that the majority of the cases would have recovered equally well had I left them quiet and well immobilised.

This is not my opinion: I believe it to be very bad for a fractured bone and the surrounding muscles to be in prolonged contact with pus. The production of leucocytes and the proteolytic phenomena which lead to the elimination of dead tissue, result in irritation of the periosteum, in sclerosis of the muscles, and in perceptible interference with recovery of function in the wounded limb. It is a mistake to regard suppuration, even of a benign nature, of war-wounds as an almost normal phenomenon; it will be asked with

astonishment in the near future how it has been possible for so important a factor in anatomical and functional recovery to be misunderstood.

To return to my cases. I do not doubt that in a few of them suppuration would slowly have eliminated some of the splinters which I removed, and union would eventually have taken place without a second operation; but I am certain that the callus produced in this way would have been inflamed, bulky, and painful. Now this result seems to me far from the ideal which should be aimed at in war surgery at the present day. There are calluses and calluses; only *aseptic* callus-formation should be sought after, and it is certainly being content with little to be satisfied with having obtained union of diseased bones with osteomyelitic extremities.

A pathological callus is a bad callus, and a reproach to the surgeon. Any fracture whose fragments are united by a section of inflamed bone, produced by diseased, swollen, and hypertrophied periosteum, encircling a cavity of varying size which contains free or fixed dead splinters, is a fracture viciously united after having been badly treated at the original operation. Similarly with sinuses. Up till now only *anatomically defective* callus has been considered vicious; that is, the cases in which the normal axis of the limb has not been restored, or articular surfaces below the fracture have been left in abnormal relation. Up to the present *pathologically vicious* callus has been very rife; every day numerous examples are seen of diseases of the callus, not formerly known to exist, and all who have had to operate on these are, I believe, already convinced that pathological callus produced by an incomplete operation at the outset is more difficult to deal with than the anatomically vicious form produced by incompetent post-operative supervision: orthopædic surgery is more sure of its results than the surgery of the results of infection.

But it will be objected that every callus is not necessarily inflamed or fistulous. Decidedly not, but chronic osteomyelitis is not the only danger that threatens a septic fracture. *Pseudarthroses* are produced by *inflammatory sterilisation* of the ends of the bone ; *dense calluses* also occur, with marginal osteitis, uniting fractures in useless limbs riddled with incisions, with sclerosed and rigid muscles and tense, shining, purplish skin. For some of these men, condemned to pain and crutches, an early amputation would often have been better than the preservation of such a limb as this.

It is for this reason that, in spite of the opinion of certain surgeons, when a fracture suppurates after an originally insufficient intervention, the surgeon should not simply wait for the suppuration to cease : *a further attempt should be made to render the injury aseptic and so to ensure the subsequent regular progress of the case.* A more or less early secondary esquillectomy will quickly succeed in rendering the wound aseptic and arrest the formation of pus : if the operator is determined to do it strictly sub-periosteally, as he easily can, owing to thickening of the periosteum, he will have the satisfaction of seeing union occur without complications after a normal lapse of time For this a far-reaching operation is necessary—and sufficient—one which achieves at once what others expect suppuration to perform, at the expense of considerable injury to bone and surrounding soft parts—*i.e.* the removal of tissue undergoing, or about to undergo, necrosis, contused surrounding skin, crushed and lacerated muscles, splinters torn away and displaced : *it should leave nothing to be eliminated spontaneously.* The esquillectomy itself should remove not only free splinters embedded in muscles or imprisoned far up the medullary canal, *but also, and principally, adherent splinters*, already diseased, which bar the way to the medullary canal, and are found with their surfaces

rough and disintegrated. Some surgeons recommend drawing subtle distinctions between splinters by their colour and resonance when struck by an instrument. There is no object in attempting such a differentiation, or in leaving in the wound useless structures of diminished vitality, which will for a long time encourage suppuration, and ultimately die. If the periosteum is carefully preserved, everything is retained in the wound necessary for the formation of an ample quantity of healthy bone; there is no risk of pseudarthrosis, and the column of bone thus formed will always be almost exactly of the same length as the original shaft, much more nearly so than in the case of a fracture in which the splinters have been retained.

FIG. 27.—Infected fracture of the humerus, three days old.

FIG. 28.—Condition of the fracture three days after total subperiosteal esquillectomy.

In every case after such intervention, and without the use of antiseptics, the wound invariably becomes aseptic in a short time (usually five or six days). If the suppuration lasts longer, the reason undoubtedly is that a splinter in a corner of the wound has been forgotten. A verification by X-rays should be carried out without delay, and any fragments remaining should be removed.

Thenceforward there need be no further fear of purulent cavities, muscular sclerosis, or neighbouring phlebitis. The callus about to form will be healthy, built up in a normal length of time by vigorous osteogenetic tissue, whose functional activity is unimpaired by any infection.

Counter-indications.—But although secondary sub-periosteal esquillectomy is indicated in recent fractures not yet united (*i.e.* less than a month old), it is nevertheless dangerous in old suppurating fractures where new bone is in contact with old and diseased bone. In this case, wide clearance, which must traverse a barrier of newly formed bone, causes violent injury in a closed space, opens up large areas for absorption, and regularly causes suddenly acute sepsis, always very serious, sometimes fatal, and likely to demand immediate amputation.

FIG. 29.—Same case as in figs. 27 and 28. Radiograph made at the end of five weeks; there was very little pus-formation. The wound not being completely closed, I was able to pass forceps in and remove the small free sequestrum seen here.

FIG. 30.—Condition at the end of sixty days. The muscles are all preserved intact. It is impossible, on seeing the play of the limb, to guess that the patient has had a serious fracture.

Esquillectomy, in such injuries which can be investigated only with difficulty, is certain to leave behind it recesses and infected fissures: only subperiosteal resection of the shaft will expose all the diseased tissue and allow of its being dressed.

For this reason, esquillectomy should never be attempted after consolidation has commenced. The surgeon should limit himself to draining abscesses and removing obvious sequestra with forceps; spontaneous elimination of the rest must be relied on, and no attempt made to get the sinuses to close until the proliferation of firm bone, enclosing the sequestra, has definitely localised the area of infection.

If the general indications given here are followed, the treatment of fractures will be found to be simplified enormously. They will run an aseptic course, without tracks of pus, abscesses far removed from the injury, secondary hæmorrhages, or elimination of sequestra. They will consolidate without forming sinuses, and, when the callus is formed, cure will be final, without complications, and without the reappearance of infection.

3. Special Indications: Particular Cases: the choice between Esquillectomy and Amputation.—So far I have only discussed splintered fractures evidently justifying an operation for restoring continuity and function; but should not the extent of the injury sometimes demand an amputation?

In other terms, what are the anatomico-pathological limits of esquillectomy?

In the upper limb I know of none, apart from irreparable injuries to blood-vessels and nerves. For anyone who can make the necessary incisions and can use a rugine suitably, there is no bone injury that can in itself necessitate amputation. If there is any prospect of preserving normal function in the fingers, a conservative operation may always be performed, apart from removing the humerus in its whole extent,

or a large extent of bone in the forearm ; even entire removal of the humerus is permissible, and I have personally resorted to it in one case. Certainly periosteal regeneration of the bone removed cannot always be expected, but an artificial structure will replace it, and no amputation stump can compare with a functional hand at the end of a flail-arm. But if muscular destruction is considerable, and if important tendons have been destroyed over a wide extent (*e.g.* severance of the flexors or extensors of the fingers), preservation is pointless and amputation should be preferred.

Similarly if, together with extensive injuries to bone and muscle, the three nerves of the hand have been severed in the arm, it is unreasonable to hope for regeneration of the median, radial, and ulnar, when their point of injury is in the region of a serious fracture. Under these conditions, esquillectomy should be rejected, and the radical operation preferred.

An isolated arterial or venous lesion does not in itself contra-indicate esquillectomy : the vessel may simply be tied in a suitable place, and the operation on the bone be performed as usual.

In the lower limb the factors concerned are different. The function of the lower limb being to support the weight of the body in an upright position and in walking, the solidity of the limb takes precedence of all other considerations ; the only conservative surgery is that which preserves function, and it is not preserving function to retain a thigh or leg which is not rigid. Esquillectomy is therefore not justified, unless followed by a regeneration of bone sufficient to ensure solidity. According to very wide investigation, apart from some exceptional cases of very extensive regeneration, I believe that any initial clearance which leaves a gap 5 to 6 in. long in a bone essential to the upright position (femur, or tibia), is a doubtful operation to which amputation is preferable. Of course esquil-

lectomy may be carried out in the first instance, amputation being postponed for some days, in order that the latter may be carried out more regularly, at leisure, and with more discrimination under aseptic conditions. It would also be possible, after extensive removal of bone, to attempt a bone-graft: early subperiosteal esquillectomy having reduced the injured area to an aseptic condition, the graft could be placed early in aseptic surroundings and have some chance of success. It would be equally possible to attempt a bone-graft from a fresh corpse. This is a reasonable alternative, for theoretically it is correct to hope for a good result; but this is not the place for discussing these methods, and they cannot affect what I have said above—there are injuries of the femur which should be recognised at once as requiring amputation.

In later stages attempts at preservation may be carried further, regeneration of bone being more abundant. But nothing should be exaggerated, and the above figures are almost a maximum.

Briefly, in present-day surgery, a fracture of the femur or tibia involving loss of more than 6 inches of the bone should be amputated at once.

Similarly, certain extensive muscular injuries combined with a serious fracture may demand amputation.

On the other hand, a vascular lesion should not, as a rule, affect the treatment which the fracture appears to require. After ligature of the femoral, esquillectomy in the thigh is still an excellent operation, provided that the shock be not too great.

Nervous lesions (severance of the sciatic) should not modify the treatment of the fracture.

The main factors governing the advisability of esquillectomy may be summarised as follows:

In the upper limb, esquillectomy should be done, whatever the extent of the injury to the bone, whenever (apart from complete cure) satisfactory recovery of function in the hand is assured.

In the lower limb, it should be rejected whenever recovery of the function of support cannot be expected.

D. Technique of sub-periosteal esquillectomy.

This is a delicate, minute, and deliberate operation, which demands time, patience, and, if possible, an exact previous knowledge of the topography of the fracture. There is every advantage in not undertaking it until after X-ray examination or complete X-ray photography from both the lateral and anterior aspects, permitting accurate estimation of the number and position of the missiles, and appreciation of the rough shape of large splinters and the general arrangement of the injured region.

1. ANÆSTHESIA.—Esquillectomy requires complete anæsthesia ; in no case should the surgeon be content with a local anæsthetic. The operation may, in fact, be a long one, and its extent is sometimes much greater than was at first anticipated. I habitually use ethyl chloride on an open mask, which allows of an operation lasting three-quarters of an hour to an hour with the advantage of immediate anæsthesia and rapid and uncomplicated recovery of consciousness, two much-appreciated features in a very busy hospital. For the lower limb, spinal anæsthesia by novocaine and adrenalin is extremely convenient.

2. DISINFECTION OF THE SOFT PARTS.—It is of great importance to begin the operation by carefully disinfecting the wounds of entry and exit. The contused cutaneous edges of each orifice should be excised ; then, the wound having been enlarged anatomically in the way described, the fascial sheath, which is usually little lacerated, and tensely stretched over the structures beneath it, is incised to the extent necessary to display the whole of the injured region. Then, without introducing the fingers in a clumsy attempt at removing fragments, two retractors are placed in the wound, permitting inspection of its superficial features, intermuscular intervals, tendons, and so on. Any

contused and lacerated muscle or other soft tissue is removed with great care by means of forceps, and the smallest fragments of clothing or soil are looked for; in fact, the whole wound is cleaned as patiently and minutely as possible.

At the exit wound even greater care is required; the muscles are often filled with osseous débris and minute splinters of bone, which should be removed with the utmost care. Gentle separation of fasciæ and muscles will reveal scraps of clothing so situated that they might well have escaped observation. Ecchymotic patches, which often undergo necrosis, are usually found in contused muscles, at some distance from the main injury; the exploration of the soft parts must therefore be carried to the extreme limits of the injured region. All suspected patches should be widely excised; even parts should be removed which appear simply lowered in vitality, and which the surgeon might feel inclined to leave untouched. These strict measures are necessary in order to avoid the disagreeable surprise, some days later, of finding large patches of necrosis in a wound which had been supposed healthy.

The entry and exit wounds, when suitably enlarged, will serve for the esquillectomy if they are conveniently situated. When this is not so, if, for instance, both are on the same aspect of the limb, or if they are too far apart, and far from the fracture, as is the case when the track of the projectile is very oblique, or if they are situated in a dangerous area, they should merely be cleaned and freed of injured tissue as above described, and the bone operation should be performed through a fresh incision made in a suitable position.

Metallic fragments are removed at once, if necessary, by means of fresh incisions. The bistoury and forceps should then be used along the track in the opposite direction to that taken by the missile until

the fracture is reached; here fragments of clothing and dead splinters will usually be found.

3. TREATMENT OF THE BONE.—Near the bone, particularly on the side of the exit wound, numerous splinters will be found. Previous to digital exploration or blind search with instruments, two retractors are introduced, and the first step is to remove with forceps all absolutely free splinters scattered in the wound. They are generally completely detached, no adherent fragments of periosteum retaining them; their tendency is to work out spontaneously, and their removal is an easy matter. This is carried on towards the shaft itself. From this point onwards *all interference must be strictly sub-periosteal, and the slightest attachments of periosteum must be preserved.* For this purpose each adherent splinter is gripped by means of small forceps * or a volsella, and the rugine is used to scrape the periosteum carefully away from it, not to liberate the splinter, but in order to leave the osteogenetic tissue covering it, in the wound. The nearer to the region of adherent splinters the greater should be the care exercised. The very natural temptation to tear away what still holds by a sharp pull or violent twisting, must be resisted, as only the fibrous tissue is separated in this way, the bone-forming layer remaining adherent to the bone; only patient and methodical use of the rugine will preserve the whole of this, together with the non-osteogenetic external periosteum. For this purpose the cutting rugine of Ollier which I have described in Vol. I (p. 30) is absolutely necessary; those who do not use it, but employ other instruments (the rugines of Farabeuf and Legouest), cannot be aware of the difference between the two instruments.

I have already stated what adherent splinters should be removed; all that are found to be loose, all whose

* Heitz-Boyer has recently had forceps made by Collin which seem to me perfect for this purpose, so good is their grip.

reduced vitality will later be further lowered even by a slight infection, and finally all which block the way to the medullary canal, and prevent exploration of it, should be removed. It is for these that the patient use of a very sharp rugine is absolutely necessary: no fragment of periosteum should be left on the bone removed, and when the operation is finished, in place of the original shaft there should be a definite cylinder of periosteum, remaining there like a mould of the original, and the outline of the future bone.

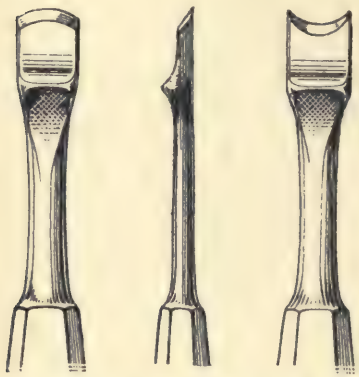


FIG. 31.—Ollier's cutting rugines with which the periosteum, including its deep layer, may be completely detached.

Often, in detaching visible adherent splinters, a large and still adherent fragment will be disturbed whose existence had not been suspected; this the surgeon may hesitate to remove on account of its length. Its removal is advisable, since shreds of material are likely to be adherent to its deep surface: at one time I left such fragments, now I remove them, having sometimes seen them become infected and inflamed. Moreover, this removal is not a disadvantage, large splinters never being circumferential; it in no way endangers the consolidation of the bone if the periosteum is left in place, and the procedure has the advantage of displaying the whole area affected by the fracture and levelling recesses where infection might develop; for these reasons it should be carried out without hesitation. In other cases, on the borders

of the injured region, where the bone is healthy, two splinters are sometimes found, 1½ to 2 inches in length, obliquely situated outside the line of the shaft, as it were like lateral splints. They may appear perfectly healthy, but if they are left they frequently become infected, and produce excrescences, contributing to the malformation of the callus. I no longer make a practice of retaining these.

It is not easy to state theoretically how far esquillectomy should be carried. It varies with different injuries; the essential point is that the medullary canal should be explored thoroughly, that no necrosing débris should remain there, so that the marrow may be scraped away as far as the injury extends and no fragment of bone remain imprisoned.

Clearance should be more complete the longer the operation is delayed, in the first place because aseptic development is assured from the outset if the exploration has omitted nothing, further because secondarily the question of free drainage is pre-eminent, since the periosteum is more easily detached and more productive.

In brief, at the outset, wide clearance is sufficient; later, it is often better to carry out total clearance.

When large splinters are present, this sometimes results in leaving nothing in the wound but the two pointed extremities of the shaft, which are in contact.

Where there is a large tangential splinter still adherent, a longitudinal groove is left in which bone is rapidly re-formed.

On the other hand, in fractures involving one large short fragment, the gap left will merely consist of a deep notch.

Where there are many small splinters, a gap 1¼ to 1¾ inches in length will often remain.

Finally, in transverse fractures, esquillectomy is replaced by sub-periosteal resection of the crushed and contused ends of the shaft, in order to produce a drainage gap about ¾ inch in width.

The essential point is in every case to perform everything slavishly with the rugine, and to preserve all the periosteum that can be found anywhere.

In the immense majority of cases, the surgeon, if he is patient and careful, will succeed in leaving a more or less complete cylinder of periosteum, or a periosteal sheath unbroken in its long axis, and this will suffice for the formation, in a normal length of time, of a good and healthy callus.

This done, and the medullary canal being well exposed, it is cleaned for about half an inch with a curette. The operator will always be surprised at what is brought to light in this way, as, for instance, fine splinters, broken scales of bone, and foreign bodies (projectiles and fragments of clothing) particularly in the regions of the epiphyses. This *curetting*, which should be performed without violence or excess, is absolutely necessary.

When the wound has been freed from splinters and the extent and variety of the injuries made manifest, it is sometimes necessary to trim the pointed extremities of the injured ends of the shaft by means of cutting forceps. In certain regions, wherever there is much cancellous tissue, and close to epiphyses particularly (notably above the elbow and in the supra-malleolar region), I have frequently trimmed the ends of the shaft with a saw : half an inch of the bone is lost in this way, but absolutely healthy bone is reached, and rapid consolidation, and good sound callus, amply compensate for this slight sacrifice in regions which are dangerous owing to the proximity of joints. There is, however, a disadvantage in this method when a secondary esquillectomy is concerned : the end of the shaft often detaches itself after some weeks in the form of an annular sequestrum, as a consequence of death of the marrow and detachment of the periosteum. This is sequestration by vascular necrosis.

Care should be taken throughout to secure hemo-

stasis : small vessels in the muscles should be ligatured, and at the end of the operation the wound should be clean and dry, without clots or oozing.

The fracture should also form, as it were, the base of the wound proper (*i.e.* injury to skin and muscles) ; the latter should not stretch over and mask it, but take the form of two truncated cones meeting at their apices, that point corresponding with the centre of the medullary canal.

4. DRESSINGS.—*The necessity of loose plugging, and the disadvantages of primary or secondary suture.* A loose mass of aseptic gauze is placed in the wound formed as above, as also in all incisions which have been required for the removal of foreign bodies or for any other reason. Drainage tubes serve no purpose and amount merely to useless foreign bodies : I never employ them.

Plugging of the periosteal cavity is necessary ; the gauze plays the part of an irritant which others expect infection to perform ; it activates the periosteum, and I do not know whether ossification would be so satisfactory without it. It also prevents approximation of the oppositing layers of periosteum, preserving the shape of the interfragmentary space in which bone-formation will take place. For the same reasons I regard infrequent dressing as advisable, and do not recommend either immediate or secondary attempts at closure of the wound. Apart from the risks of infection caused by immediately closing the wound, I consider that the method should be rejected because it prevents reactivation of the periosteum which is effected by plugging.* I have on several occasions seen consolidation occur in twenty-four hours after the third or fourth dressing, as if the irritant effect of

* Ollier taught that everything should not be sacrificed to the desire for a rapid cure by first intention. Aseptic secondary closure appeared preferable to him from the point of view of bone-formation. Everything that I have seen up till now leads me to believe that he was right.

the dressing had suddenly released a new activity in a still perfectly soft callus.

After plugging, the limb is heavily padded and carefully immobilised by one of the methods which will be suggested later for each type of fracture. The dressing is left in place for a period of eight to fifteen days, sometimes longer; in fact, after such an operation as has been described, asepsis of the wound is almost invariable, and this allows of everything being left in place, absolute immobility being ensured; when the gauze is removed, a healthy surface is found, oozing blood, and at the bottom of the wound, a perfect granulating membrane formed from the layer of periosteum. The dressing is repeated with aseptic gauze, gently introduced into the wound, and is allowed to remain in place there for a further ten days. After three or four dressings, the onset of consolidation may be expected.

This process, following on well-performed subperiosteal esquillectomy giving normal results, occupies from thirty to sixty days according to the region involved. The bone is often solid before healing of the superficial wound is complete. But the course taken by this aseptic wound is so simple that I see no great advantage in closing it by sutures.

Little modification is required by a septic condition of the wound: if the soft parts are seriously infected, swollen, and œdematous, I prefer a dressing of moist gauze, soaked in concentrated saline (10% to 14%), to a dry dressing. This should be left in place for two or three days; it produces profuse suppuration, the pus being of a greenish-yellow colour. When it is removed, whitish patches will be found scattered over the granulations; this organic débris is removed with a swab or forceps, and the wound is well dried and treated by heliotherapy, or by a stream of hot air. Under the action of the sun, the wound becomes glazed, then bright red, and oozes a

considerable amount of lymph, as I mentioned in connection with wounds after articular resection (see Vol. I, p. 29), submitted to the action of the sun. With hot air the effects are the same, but slightly less pronounced. A second moist saline dressing is kept applied for a further two days, after which it is generally possible to resort finally to aseptic gauze dressings, aeration, heliotherapy, and hot air.

I shall not discuss further the advantages of systematically employing physical agents in the restorative treatment of wounds: I emphasised them sufficiently in Vol. I. I merely repeat that aeration, heliotherapy, and the hot-air douche are to me a fundamental feature in the treatment of all gunshot wounds, and that up to the present we have no more effective means than the sun for reducing the severity of a wound and accelerating its spontaneous healing.

FIG. 32.—Annular sequestrum from the end of the shaft of the femur, removed after two and a half months, in a case in which esquillectomy had been performed at the front.

The formation of the callus should always be watched by means of X-rays: several radiographs are necessary for verification, particularly after comparatively late secondary operations: in these cases the edges of the wound are sometimes seen to have become œdematous, and some thick pus appears, particularly if the ends of the shaft have been trimmed with a saw; a radiograph of the fracture at this period reveals a small notch on the edge of the shaft; this is a small sequestrum which has just become detached, and its removal by forceps is sufficient to clear up this slight complication, which could have been anticipated if the progress of the fracture had been watched by X-rays, and the successive stages in the formation of

a callus followed by this means. If the treatment is carried out in this way, none of the complications by infection, of which so many surgeons speak, will occur: far-reaching tracks of pus will not develop, neither will associated arthritis, lymphangitis, nor secondary hæmorrhage. Progress will be simple from first to last, and cure will be effected without a trace of the troublesome sequelæ which for years afflict the unfortunate men whose wounds their surgeons have not desired or dared to disinfect early and completely.

It is often surprising, particularly after a total secondary esquillectomy, to note the rapidity with which the callus forms. I mentioned on p. 50 certain statistics which will undoubtedly appear exaggerated to some. They are, however, absolutely exact.

But it should be added that a callus formed in so short a time is not very hard, and that immobilisation should be continued for a long period after consolidation has been ascertained. Recently in a case in which I performed a secondary esquillectomy for a sub-trochanteric fracture, in which the limb could be raised on the forty-second day, the callus became bent between the seventieth and eightieth days, the extension having been removed on the sixty-second day, and the patient having left his bed and walked at about the sixty-fifth. I applied extension on the ninety-third day, and succeeded by the use of weights (7 to 8 kilos) in correcting it almost completely.

There should therefore be considerable delay before free use of the limb is allowed: sixty days at least for the upper limb and 120 for the lower limb. I shall resume this subject in connection with particular fractures.

II. The Reduction of Gunshot Fractures

Reduction in these cases is not, so to speak, a distinct operation, the result of co-ordinated movements such as are carried out for simple fracture of the radius, or for Dupuytren's fracture, for instance. The multiplicity of fragments and splinters, the incalculable element introduced by muscular laceration and the irregularity of the area affected, render this impossible ; and when there is definite over-riding, as in fractures of the upper part of the femur and humerus, the muscular force to be overcome is such that the most vigorous movements at the time cannot reduce them. After such wide clearance as has been described, the matter is different : reduction is almost always practically realised when the operation is over, or, at least, it is very much facilitated ; frequently it consists simply in immobilising the limb in the physiologically correct position ; in any case, prolonged extension always gives the result desired.

In theory, three methods of reduction may be employed :

Reduction by open operation (fixation by plating, etc.),

Rapid reduction by manipulation,

Slow reduction by continued extension.

1. Reduction by open operation.—The invariably septic condition of all gunshot wounds absolutely forbids reduction by this method as practised by Lambotte and Lane in the simple fractures of civil practice ; attempts should not be made to restore large fragments and splinters to their original position, supporting the whole by metallic apparatus (bronze wire, clasps, or plates). Certain surgeons may have been tempted to do this at the beginning of the war, on examining a fresh wound during the first few hours, before any signs had appeared of the serious infection which was developing there. The rapid

appearance of dangerous septic conditions has absolutely and finally barred the renewal of such attempts : in some cases sepsis was fatal, others had to be amputated, in others widespread necrosis of bone occurred. I have seen shocking examples of the latter at medical boards.

On the other hand, it is quite conceivable that after free preventive esquillectomy, this method of reduction might appear tempting : it is so simple to use a plate or wire to unite the two contiguous ends of the shaft, when the injured region, its surfaces made plain, cleared of all infecting débris and all its splinters, is clean and uncomplicated.

I am persuaded that this could be attempted with frequent, if not constant, success on the single condition of keeping the wound widely open and dressing the osseous region itself without obstacle. Although never having actually done this, with my experience of the progress of fractures after free esquillectomy, I shall not hesitate to attempt it under favourable conditions in regard to supervision and apparatus.

But in practice, this reduction with immediate reunion of the bones by osteosynthesis is not advisable and should not be made a routine procedure : war surgery should before all things be safe surgery ; every case should be enabled as soon as possible to be evacuated without danger ; a minimum of supervision should be required, for it is possible that the patient cannot be closely observed ; an operation case, during the hours following the operation, may be finally separated from the surgeon and sent on a long journey. Artificial union of bone, even under the aseptic conditions which I admitted in theory above, may prove, if the operation is not absolutely complete (which is always possible), to be the origin of serious complications which must not be risked in the case of wounded men : it may only be attempted when the operation takes place in the earliest stages, and when constant

and prolonged supervision is assured for the patient. In any other circumstances, it should not be performed on any account.

It also possesses the disadvantage of perpetuating the shortening when a reduction of the interfragmentary space has occurred, assuming that periosteal proliferation succeeds in filling the gap. Finally, it is unnecessary: *free esquillectomy, such as should be practised, simplifies the region of fracture to such an extent, that reduction itself is realised by it:* it is enough to immobilise in good position to ensure automatic reduction, or an easy realisation of it with the help of continuous extension.

Briefly, *sub-periosteal esquillectomy is the best operative method of initiating a good reduction.*

2. Rapid and forcible reduction.—This consists in restoring the correct position of the fragments by a single effort by means of powerful traction and suitable manipulations. This is very easy in certain regions, when the fracture has been widely cleared; it is, on the contrary, very difficult, sometimes impossible, whenever the fragments have been left in place and some are laterally displaced, as is usually the case. Marked displacement is the result of strong muscular action which can only be overcome with difficulty under an anæsthetic, and much less without it.

Immediate reduction may be attempted in two ways, either by means of manual or instrumental means followed by the immediate application of immobilisation apparatus, or by immobilising apparatus with adjustable springs which apply rapid extension and correct the displacement at once.

In the former case (taking as an example a fractured thigh), an attempt is made, under an anæsthetic, by traction in a definite direction, to bring end to end the two fragments of the shaft; when this is effected, they are fixed in position by a large immobilising

plaster casing applied while the pull is being exerted, and only removed after consolidation has occurred.

In the latter, Delbet's apparatus is used for a fractured thigh. This appliance, which will be described later, gives very powerful extension, and reduces serious displacements in a few seconds.

But sudden reduction is often painful; frequently it is scarcely bearable unless it merely attempts to place the lower fragment in line with the upper, pending immobilisation of the limb (as in supination of the hand in fractures of the forearm); further, it does not always give accurate results, as is proved by X-rays, and in the main there is every advantage in the slower method by continuous extension. This is so true that Alquier, the surgeon who has perhaps had the most experience of Delbet's apparatus, has completely given up rapid reduction.

Immediate reduction is only demanded by one circumstance; the improvised application of a temporary apparatus for transport when a rapid evacuation is expected, for it is important to immobilise after as perfect a reduction as possible. But absolute confidence should not be placed in the results apparently obtained, and when the transference of the patient has been effected, the original apparatus should not be retained permanently unless it is shown by X-rays that the desired reduction has been obtained. This is unusual, and as a rule it is better to resort to progressive reduction by continued extension, a slow and gentle, but sure, method.

3. Gradual reduction.—This is the preferable method: the ceaseless action of continued extension has a marvellous reducing action, giving no pain and abolishing muscular contraction, which obliges the bones to resume their original positions, restores structures to their normal relations, and thus enormously favours drainage and repair.

It is advisable in any region, and can only be wholly dispensed with in the forearm.

It can be produced in different ways :

(*a*) *Continuous extension by Weights.*—The usual procedure is an extension by weights fixed to a stirrup applied to the limb by adhesive plaster, or by an adjustable screw pulling on the stirrup itself. The traction is exerted on the lower fragment through these bands and the soft parts. It is of advantage to apply the stirrup, when possible, to the whole length of the limb as far as the groin or axilla, wherever the fracture may be situated, but unfortunately the existence of wounds is often an obstacle to this. The strips employed should preferably be adhesive,* applied directly to the shaved skin ; they should be applied over as wide an area and as high up the limb (*i.e.* leg, thigh, arm, or forearm) as possible, in order that the circular or overlapping strips that fasten parallel ones to the skin may not slip down enough to cut into the skin just above the joint below, which is extremely painful, particularly at the knee.

The strips to form the stirrup are put on parallel to the limb, and made fast by others wound spirally round it. The tension is distributed in this way, which is preferable to winding only two or three turns, which rapidly become painful. On the other hand, they should approach as near as possible to the region of the fracture. If possible, there should not be a

* Failing leucoplast, and in place of the old diachylon (lead) plaster, different adhesive substances may be used, liquefied by warming in a water-bath, and applied to the strips of bandage. Amongst the very numerous formulæ which exist, the following has been recommended :

Rosin (colophane) . . .	50 grammes
90 per cent. alcohol . . .	50 ,,
Venice turpentine . . .	5 ,,
Benzine	25 ,,

This is spread over the limb with a brush, and extension bands of calico are laid down upon the skin. I have had no experience of this method.

joint interposed between the point of application of the force and the bone upon which it is to act. It is wrong to exert traction on the leg in order to pull on the femur, since this permanently upsets the knee, causing terrible difficulties in the future. Traction should be exerted in a definite direction suited to the particular case : it should always be exerted in a line with the upper fragment, which is differently acted upon by the muscles, according to the height of the fracture : thus, for instance, the lower fragment of the humerus or femur should be abducted in fractures situated slightly above the middle of the shaft.

There is one further remark to make on the subject of continuous extension by weights : permanent traction is more efficacious when exerted on parts of limbs whose muscles are relaxed. The relaxed position in the upper limb is that of semi-flexion of the elbow and pronation; in the lower limb, semi-flexion at the ankle, knee, and hip. These positions should be utilised, since continuous extension is more easily tolerated and more efficacious when these physiological considerations have been taken into account. This is of great importance in fractures of the thigh.

Continuous extension by weights, based on these theories, is the best method of reducing fractures, and should be employed for preference. It has also the inestimable advantage over all other methods of being easily applicable anywhere, and by very simple means, which in war surgery is an essential point.

Continuous extension by weights may also be established by means of a *laced boot* or *plaster gaiter*, on the plantar surface of which a small ring is fixed for traction. But a plaster gaiter is often painful, and such means have the further disadvantage, if they are employed for fractures of the thigh, as is usually the case, of exerting the pull from too great a distance, stretching the knee which is already distended by slight hydrarthrosis.

(*b*) *Extension by a transfixion Nail or metallic Loop.*—A more precise, or at least more direct, method, is that of extension by means of a nail, the latter transfixing either the femoral condyles or the os calcis. Many surgeons are quite reasonably not attracted by the idea of transfixing a bone. But in spite of its disadvantages, if the method gives better results than others, there is no reason for hesitation in adopting it. Those who have employed it say that the method is painless and safe, and brings about reduction of the most serious displacements. I have had occasion to examine several cases which had been treated in this way for fractures of the thigh. The results were very mediocre: there were shortenings of from 2½ to 3 inches, and X-rays showed considerable overriding which had not been corrected at all.

On the other hand, if the fracture is carefully cleared by free esquillectomy, reduction is easily obtained by continuous extension on ordinary lines, always provided that it is applied in the right direction. During twenty months of war, I have not yet seen a fracture which I could not reduce satisfactorily by the usual methods. But it is obvious that all these methods will fail if the line of traction does not correspond with that of the upper fragment.

I see, therefore, no necessity for extension by means of a nail; it uselessly complicates the treatment, and should never be employed.

Is this also true of Finochietto's modification which Chutro has recently introduced into France for fractures of the thigh?

This method consists in passing a strip of metal over the upper surface of the os calcis in front of the tendo Achillis. A metal stirrup, through which traction is exerted, is fixed to this strip (figs. 33, 34, 35). It may be left in place for some weeks without inconvenience.

Finochietto's stirrup is a decided improvement on

extension by means of a nail; it is a refinement of what some surgeons have done by fixing a simple loop of wire in the same position; theoretically, the same objection applies to it as to other methods of traction from a distance—it pulls on the leg and thus tends to produce disturbance at the knee. Chutro and Heitz-Boyer assert that the extension is perfect, and produces no such undesirable effect. This should therefore be a procedure to hold in reserve, and to utilise if it is actually proved that after powerful traction the knee is not dislocated, for a fixed joint is preferable to a flail one.

Lastly, the extending force may be exerted by *elastic traction*. This is only used exceptionally; apart from the appliance for fractures of the thigh (to be described later), invented and used by Sencert, I know of no example of it.

The weights may be replaced by an adjustable screw apparatus which easily gives very powerful continuous extension.

(*c*) *Extension by sliding or spring Appliances*.—There is an entirely different type of appliance in which continuous extension is produced by springs, and by shafts sliding one over the other, adjusted by some kind of mechanism.

The typical appliance of this type is that of Pierre Delbet, in which extension is obtained by means of a flanged spring which forces apart two shafts which slide in a tube and are each connected with and act on the limb, the one above, and the other below, the fracture: above on the axilla, for instance, and below on the forearm, which is kept flexed at right angles by means of a sling.

Many excellent appliances of different kinds have been invented on this ingenious and practical model. Usually they consist of two plaster collars of varying length, incorporated with two hollow shafts sliding one over the other and enclosing a spring which tends

continually to separate the two resisting points, that is, the two plaster collars; the latter by means of the sliding concentric shafts and the pressure thus con-

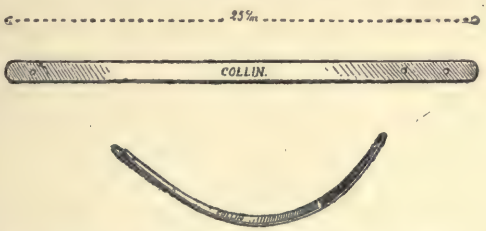


FIG. 33.—Metallic strip and its guide (Pedro Chutro).

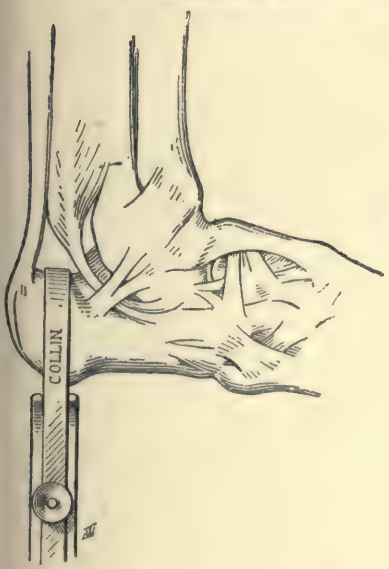


FIG. 34.—Position of the metal strip in relation to bone and tendons (Pedro Chutro).

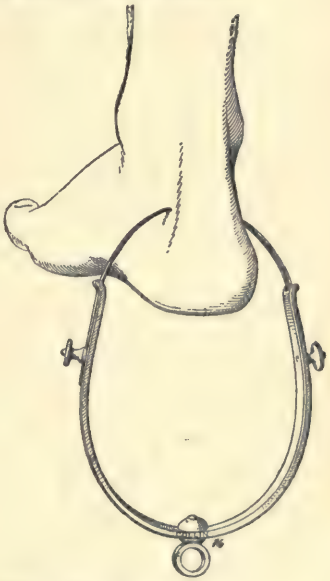


FIG. 35.—The apparatus in place (Pedro Chutro).

tinuously applied to the lower collar submit the limb to permanent extension.

It will be seen that a large number of appliances

exist for producing continuous extension in fractures. All can give and have given good results, for what is of more importance than the variety of appliance used is the sound application of the fundamental principle on which all are based ; the technical method is a matter of convenience, and its importance is secondary.

As it is very difficult to choose between the numerous procedures recommended, I shall discuss in connection with each fracture the appliances which I use, without even alluding to those of which I have no experience ; this does not mean that they are faulty, or should be rejected.

Lastly, *after free esquillectomy permitting of infrequent dressing, the question of apparatus is much simplified*, since the progress is clinically aseptic, and it is usually necessary only to dress the wound at long intervals.

III. The Immobilisation of Fractures

All fractures should be immobilised for a long period. It is too often forgotten that immobilisation is at the root of all treatment directed against infection : without it, the injured area is constantly subject to further trauma, further infection of the wound is continually being produced, great increase in the virulence of the infection being the result. For this reason it may be said that immobilisation is a prime necessity of disinfective treatment ; it is also indispensable for avoiding pain, and for maintaining reduction, thus favouring the formation of the callus.

Theoretically the best method of immobilising a fracture consists in uniting the fragments, either by wiring, a plate (Lambotte), or by a clamp of the type devised by Dujarier.

This *operative fixation* of the fracture, however, is rarely, and should not be generally, employed. At-

tempted indiscriminately, at the beginning of the war, by surgeons to whom the constant infection of gunshot fractures was unknown, it brought disaster and was condemned. It might, however, perhaps be excellent in certain cases, after careful operative disinfection and free sub-periosteal esquillectomy, if the object were merely to produce provisional union of the bones, and the wound were kept open. But it should not be supposed that this primary osteosynthesis after sub-periosteal esquillectomy is applicable under all conditions and to all cases. Useful and beneficial if operative disinfection has been complete, it becomes dangerous if some overlooked débris threatens to provoke the development of acute osteitis. It should also only be attempted in cases operated on early, by a trained surgeon who is certain of being able to look after the case for a long period.

Further, all cases in the above categories do not justify it. It might be indicated in all aseptic fractures in which, after sub-periosteal esquillectomy, only two pointed extremities of the shaft remain, meeting at their apex; it would then be easy and useful to unite the two fragments by a Lambotte plate. But when, on the other hand, clearance has given rise to extensive loss of bone, and a fairly large interfragmentary space, osteosynthesis is not advisable, since it would cause too great a shortening, whereas a periosteal callus, filling the interfragmentary space, will unite the two extremities of the bone with very trivial diminution in length.

When it is added that it is not without danger in infected fractures, it will be agreed that it is only advisable in exceptional instances.

Lastly, operative fixation cannot suffice in itself; it must always be reinforced by an immobilisation appliance. This consideration decidedly reduces its value.

Initial fixation by metal is therefore likely to re-

main an unusual method * at the front, and recourse should be had usually to the indirect methods of immobilisation. The latter are numerous, many are excellent, but their use is not always satisfactory, because the fundamental rules of good immobilisation are not understood, because sometimes the conviction of its necessity is not sufficiently strong, and lastly, because there is sometimes an unjustified conviction of its riskiness. In reality, it should be stated as a principle that such a thing as too rigorously or too completely immobilised a fracture cannot exist. Immobilisation after esquillectomy should be the principal care of every surgeon.

A. The principles governing immobilisation.

1. The principles of Bonnet.—Fixation has for a long time been a difficult problem to all who have not paid the closest attention to the early disinfection of fractures; they have continually to fight suppuration, and hence are compelled to dress the wounds at least once daily, they have to watch closely the spread of infection, to make complicated and repeated arrangements for drainage, to carry out secondary esquillectomies, and to irrigate freely with antiseptics in order to sweep out necrosed organic débris. Suppuration prevents the accurate adjustment of any fixation appliance; dressing is difficult and painful; continuous friction between the opposed fractured surfaces results in numerous small local injuries which promote infection, thereby interfering with disinfection and repair.

Attempts were made to abolish these disadvan-

* While correcting the proofs of this book, I received two cases in which the large splinters had been surrounded by a wire suture. After three months there was no consolidation, and the wire gave rise to a permanent sinus. I removed the wire, and consolidation occurred soon afterwards, but the fragments were necrosed and had to be removed. After eight months, these patients have not yet recovered. There was therefore no advantage in the method.

tages by reintroducing the interrupted plaster casing, a large number of which were badly conceived and violated the fundamental principles of fixation. By continually evolving new appliances, some very ingenious solutions have been found in spite of very real difficulties, and some of these innovations will live in surgical therapeutics, but this was *approaching the problem from the wrong side :* the only method of simplifying dressings, and of rendering them painless and harmless, is to disinfect the area of the fracture at the outset, and thereby avoid suppuration in it. It then becomes much easier to arrange for an ideal immobilisation, and above all, nothing then interferes with its maintenance.

The only ideal immobilisation is that which fixes the extremities of the bone exactly in a definite position, without possibility of displacement in the region of the fracture, and without causing pain to the patient.

That this may be so, to follow the classical and often misunderstood principles of A. Bonnet, *the articulations above and below the fracture must be immobilised*, that is to say, the whole limb must be immobilised.

This fixation, which must be maintained until consolidation has occurred, must be as rigorous at the beginning as at the end—at the beginning, to avoid pain and contribute by rest to the disappearance of infection ; at the end, when the callus is about to form, in order that the new bone may assume a correct shape and that there may be no deformity of the limb.

But immobilisation thus understood has the disadvantage, according to its own principles, of fixing the neighbouring joints. This is of little importance if it is not maintained too long ; if, on the other hand it be prolonged, muscles atrophy, joints stiffen and when at length the bones have united, the functions of the limb have been impaired as a direct result of the

immobilisation. The result is therefore far from being perfect.

As a matter of fact, when he was studying immobilisation and formulated the rules which the entire world has adopted, Bonnet had only articular pathology in view, and did not consider fractures. It is certain that, to immobilise a joint, the two epiphyses forming it must be fixed. Now these cannot be maintained in complete repose unless all movement is suppressed in the epiphysis of the other end of the bone, the slightest displacement of which reacts on the opposite end of the lever (*i.e.* of the shaft). This amounts to stating that the whole joint must be immobilised, and no other solution but that of A. Bonnet is possible. But in shaft fractures the case is different, and for these the problem may be studied differently, an attempt being made to give the joints free play.

2. New principles for the immobilisation of fractures.—As a matter of fact, if the circumstances are pictured, it becomes evident that, to immobilise a fracture, there is no need to fix the joints above and below it: it is enough to fix the fragments concerned in the desired position by means of a metal shaft taking purchase against the projections of the corresponding epiphyses, or on the soft parts surrounding them, that is, above and below the joints situated below and above the seat of injury respectively. The theoretical appliance which realises this, is as it were a form of external prosthesis, buttressed against the epiphyseal projections, closely comparable, in fact, to the internal prosthesis represented by a Lambotte plate. After this the neighbouring joints are free, and can move, if not normally, at least enough to preserve their flexibility. Pierre Delbet succeeded in reducing this to practical form, evolving appliances which gave extension and at the same time only involved the actual segment of the limb concerned,

leaving the neighbouring joints relatively at liberty while buttressing close to them, either against some lateral support (the edge of the axilla, for instance), of which use is made in the case of spring appliances, or on fixed bony points of support utilised by means of a plaster casing. Descriptions of these appliances will be given later. For the present it is sufficient to mention an ingenious practical realisation of the principles stated above.

3. THE PRINCIPLE OF SLING SUSPENSION.—This solution of the fixation problem which certain American surgeons have given, is entirely different and even more simple : it is really a paradoxical solution, since it appears to suppress immobilisation itself, or at least immobilising appliances, but it is nevertheless excellent. It consists in placing the limb in a kind of hammock, suspended in the air and kept in position by weights, and applying continuous extension ; the opposing force is exerted by the weight of the elevated limb. Fixation is due to the fact that movement of the injured region is only possible *in toto*, and cannot occur within the region. This form is excellent ; it possesses the advantage of preventing all friction due to local muscular contraction, suspension abolishing all resistance and allowing only of displacement *in toto* of the fractured region which itself is fixed by traction and counter-extension.

In fact, fixation in space is realised by preventing transmission of the forces of movement, the principle utilised being that of suspension from a universal joint.

B. Means of securing immobilisation.—There are three possible methods of immobilising, which innumerable appliances have been designed to realise. All can be employed, but each is indicated by particular conditions. It is necessary to understand their management thoroughly, not only their instrumental, but their therapeutic use.

It is this that I shall endeavour to explain in studying the different types of fixation according to the principles on which they are based.

Later I shall indicate which should be chosen in the case of any given fracture.

1. Fixation according to the classical rules of A. Bonnet.—This is the classical form, which should be thoroughly understood, for it remains the fundamental method, and the method for cases of urgency; ignorance of it is inexcusable. *During an influx of cases, it is the only possible method; during evacuation it is the only advisable method; in a war of movement, no other can be employed.*

There are numerous ways of arranging it—that is, of immobilising the fracture by immobilising the whole limb, but they are very far from being of equal value.

(*a*) *Metal splints.*—Whether made of iron wire, iron gauze, or aluminium, these are convenient, quickly applied, and, except for the thigh, furnish an excellent means of temporary fixation: they represent material always ready at hand and quickly applied, they do not alter in shape or become foul, and they can be sterilised by flaming at each dressing. Delorme's models in aluminium are very light, and do not interfere with examination by X-rays.

In spite of such qualities, these splints are never efficient appliances; they immobilise only indifferently, they mould themselves to the contours of the limb and not of the bones, and consequently cannot really maintain a reduction; as soon as the padding becomes deranged or the bandages loosen, they no longer immobilise at all. Lastly, they do not effect the continuous extension which lies at the root of the treatment of almost all fractures.

Trough splints are not suitable apparatus for treatment; they are only temporary and provisional appliances, and should not even be used as makeshifts for a

journey if there is time enough to make better arrangements.

(*b*) *Reed-blind material.*—This is a war invention. It was first used in the form of a sheath for rapid temporary fixation (Pauchet), then in the form of splints (Eynard), and finally as plaster-splints (Eynard-Santy).

Three to five thicknesses of ordinary reed-blind material, 3 inches in width, are superposed, each surface being padded with a layer of cotton-wool, very useful long splints being obtained in this way.

For fixation of the *lower limb*, three may be used: one, about a yard in length, is placed posteriorly, beneath the leg, bent up at right angles to follow the outline of the heel: two others, 30 inches long, are placed laterally, one on each side of the leg. The whole thing is held together by the application of tarlatan bandages.

When the thigh and hip are concerned, it is well to use thicker splints, consisting of four or five thicknesses of material. The posterior one, bent up at the heel, is from 52 to 60 inches in length, reaching as high as the waist and taking a firm purchase there. An external lateral splint passes from the heel to the iliac crest, and on the internal aspect is a third one, its upper extremity heavily padded; at the genito-crural fold this takes its purchase from the ischio-pubic ramus. Securely fixed by a large spica bandage, these splints can be made in a few minutes to form an appliance in which the patient suffers no pain and which offers strong resistance to movement.

The use of blind-material is equally simple and practical in the *upper limb*.

If the forearm, elbow, or lower extremity of the arm is to be immobilised, two splints 2 inches wide and consisting of two or three thicknesses are sufficient. After flexing the elbow at right angles and pronating the forearm, a postero-external splint is

first fitted to the extensor aspect of the limb, after being broken at the elbow. It should be a yard in length, passing upwards as far as the posterior border of the axilla, and downwards flush with the ends of the fingers.

A second shorter (18 in.) slip is placed along the flexor aspect after being suitably bent.

The blind splint is a good appliance in early stages, but it possesses the disadvantage of being fixed by the dressing itself, and must be removed whenever the wound is to be exposed; it is also permeable by secretions. This has led to the use of plastered blind-material, which is equally manageable and at the same time more rigid and resistant.

This consists of a form of casing made up of three or four thicknesses of material; this casing is directly surrounded by two thicknesses of stiffened tarlatan, kept in place by a few stitches; by this means the splint, dipped into liquid plaster, is satisfactorily impregnated, and retains sufficient plaster to set well. The appliance is completed by plaster bands connecting the splints and forming a certain number of rings at intervals. After this, free access to the wound, and supervision of the injured limb in its entire length, are easy matters.

These excellent appliances give good fixation and are easily handled.

(*c*) *Plaster appliances*.—Plaster is the most widely applicable and practical method of immobilising fractures: it meets all requirements, and is so convenient and manageable that nothing can take its place. Certain appliances and arrangements, may, in a given case, be more comfortable and assure a better result, but if there were to be only one procedure for treating fractures, plaster would certainly be chosen. Happily, however, this is not the case, and selection is possible. This does not alter the fact that in present-day surgery, and war-surgery in particular, plaster appliances,

in spite of certain disadvantages, remain as the basis of fracture treatment. Some surgeons criticise them severely; they do not, however, understand their use, for it is a definite art. A good plaster should not give pain, cause ulceration, or grip too tightly, and should immobilise thoroughly. It is all a matter of care.

Method of making a Plaster casing.—There are two types of plaster appliance, troughs and circular bandages. In principle, the troughs are removable and the circular bandages are not. In practice, windows of varying size are left in the circular form, and the different parts are connected by plaster or metal bands; in this way the wound is left exposed as desired so completely and so well that circular plasters are now the appliances that really allow of convenient dressing, troughs no longer being employed except for wounds which are very infrequently dressed.

In any case, a plaster must be large, and moulded to the projections of the limb. By "large" it is meant that it should immobilise the two adjacent joints according to the principles of Bonnet.

The appliance should not be directly applied to the skin, even if the latter has been shaved and greased. It is better to interpose a thin layer of flannel, gauze, or a few turns of bandage without reversing. It is useless to pad any bony projections except the patella; it is better to model the plaster round them with the thumb, and not on them. Ulceration is avoided in this way. The best isolating material in the case of a trough is ordinary paper, rolled about the dressing and the limb when the plaster casing is about to be applied.

The plaster which should be used is plaster of Paris (modelling plaster). If it is at all old or stale its properties may be restored by heating for a few minutes. A definite quantity (about 4 kilos) is required for a plaster for the lower limb. It is often well to mix it in two successive portions in two neighbouring

basins if a complicated appliance in several pieces is to be made.

Dressed tarlatan (tarlatane gommée) is the vehicle of the plaster, and is employed in the form of bandages or strips. *The bandages*, which can easily be made in the hospital, should be 5 to 10 yards long and 4 to 6 inches broad. They are prepared for use by being rolled up after passage through a basin full of dry plaster, or by rolling them with one hand, while the flat of the other spreads the plaster over the tarlatan, which lies flat on the table. According to Calot, who has written a practical book on plaster appliances, full of useful advice, the outcome of long experience, about 2 oz. of plaster are required for each yard of tarlatan 6 inches wide, 10 ounces for 5 yards of bandages. When about to be used, the plaster bandage is plunged into a basin half full of slightly warm water (not saline). It is ready for use when air-bubbles cease rising, *i.e.* in two to three minutes. A fresh bandage should therefore be placed in the basin after one to two minutes, if several are to be used. Excess of water should be squeezed out before the bandage is applied. The application should begin at the extremity of the limb, passing upward towards the trunk, in order to avoid initial constriction of the veins.

The plaster usually sets ten minutes after its application was begun.

The turns should be regular and without reverses; the left hand methodically arranges and smooths the bandage, while the right applies it by simply unrolling it without pulling or tightening: it is easy to predict how the apparatus will be tolerated by watching how it is put on.

I repeat what I have already said on the subject of bony projections; the thumb should be carried round them so as to model the bandage closely to their contours in order that they may support and fix the

casing, and therefore not be ulcerated by it. If desired, a circular plaster may be cut open down the long axis of the limb, giving two halves easily removed and reapplied.

Trough splints are made with tarlatan slips consisting of eight to twelve layers. They should be cut longer than appears necessary; they can easily be cut down later to the desired dimensions. In width they should not exceed half the circumference of the limb; there is a tendency to make them too wide, covering part of the anterior surface of the leg or forearm, and causing a certain amount of difficulty in their removal. Adaptation to the flexures of the limb is ensured by cutting notches that allow one part to ride over the other when the strip is bent.

The liquid plaster for the splint should be made in a large basin with cold water, without salt. According to the classical formula, more plaster than water should be added, five parts of plaster to four of water. There is an advantage, however, in thickening the paste a little further, by the addition of more plaster than is prescribed, and, like Calot, I use for choice five parts of plaster to three of water (by volume). An excellent but slower method consists in sifting the plaster through the tarlatan, which is stretched over a basin, until the powder floats on the surface of the paste like small pieces of ice in water.

When the paste is ready it should be used at once without further dilution or thickening. It is better to start afresh than to attempt any alteration in its consistency: any attempt at improving it almost always makes a failure of the appliance.

Whatever the type of appliance used, it should not cover the wound; gaps are cut in the splints, or openings are made. To recognise the position of wounds and to know where to cut out an opening, it is enough to mark the place on the dressing by placing a few drops of tincture of iodine on the gauze immediately

previous to applying the plaster ; a violet stain on the appliance will soon mark the position of the wound to be uncovered.

These windows are made with a bistoury or a shoemaker's knife about half an hour after the plaster has set ; they should expose the skin widely round the wound, and their edges should be covered with gauze or bound with strapping.

If the wound or wounds are very extensive, and if the fracture is suppurating profusely, recourse may be had to interrupted splints. I shall discuss their use later (see p. 101), but confine myself for the present to describing their construction.

The principle is to apply two close-fitting circular plaster bandages, one above and one below the region of the fracture, and to unite them by metallic loops, or by plaster loops reinforced by wood, wire, or tow, the ends of which are incorporated with the plaster. In constructing them, the fundamental principles of fixation have often been misunderstood—thus metallic loops passing from the shoulder to the forearm have been recommended for fractures of the humerus. These gross therapeutic errors are no longer made at the present time, and the interrupted appliances now made rigidly fix the two bony segments to be immobilised.

The circular plaster bandage should extend sufficiently far along the limb in each direction to render the joints above and below the fracture immobile.

Briefly, interrupted appliances which originally left too much of the limb exposed tend at the present time to be nothing more than circular appliances with bracketed interruptions. This development was inevitable ; the laws of fixation demanded it.

The circular plaster bandages are applied according to the usual rules, and two or three metal loops, prepared beforehand of the required dimensions and

bent in the right place, are fixed on each of them with a plaster bandage.

The bandage may be carried from one circular part of the splint to the other by covering the metallic loop with it, or, on the other hand, the metal may be left exposed.

The same thing may be done with any more or less rigid kind of support, or more simply still, plaster strips may be constructed from a fairly long piece of bandage. For this purpose it is enough to unite the two circular portions by a few longitudinal strips of plastered bandage, fairly long and not too tightly stretched, round the ends of which a few turns are made with another bandage to cover and secure them; a series of soft connecting loops is thus obtained, which may be pulled outwards from the limb by the fingers and kept in that position until the plaster dries.

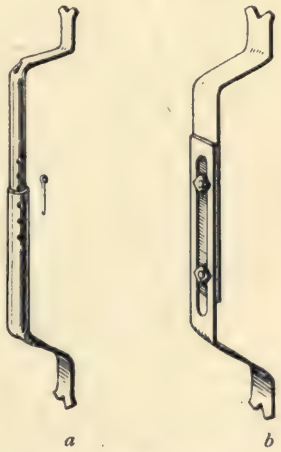


FIG. 36.—Metal loops with (*a*) a spring, (*b*) nuts.

These appliances are interesting, but as a matter of fact, however well made they may be, they possess great disadvantages: very soon the limb becomes loose within the casing enclosing it; it begins to have too free play, and fixation is less rigorous; overriding occurs, and some degree of angulation between the two ends of the shaft is produced, so that the actual therapeutic and orthopædic result obtained is mediocre.

Hence the idea of *plaster casings with extensible metallic brackets, or brackets consisting of tubes sliding*

one within the other, i.e. continuous extension plaster appliances. These are actually only copies of Pierre Delbet's appliances. But these modifications are convenient, and their use should become general.

To construct them it is enough to replace the ordinary flat metal loops by metal slats sliding one over the other which can be fixed by means of a wing nut, or by hollow rods of different diameters sliding one within the other, or again by shafts with a spring resembling those of Delbet's apparatus. By exerting traction on the end of the limb, it is possible, if necessary, to produce the extension judged to be useful. Perforations and a pin allow the tubes to be fixed in any position. Excellent and compact appliances are constructed in this way for the leg (see fig. 37); they are easily improvised everywhere and are of great service.

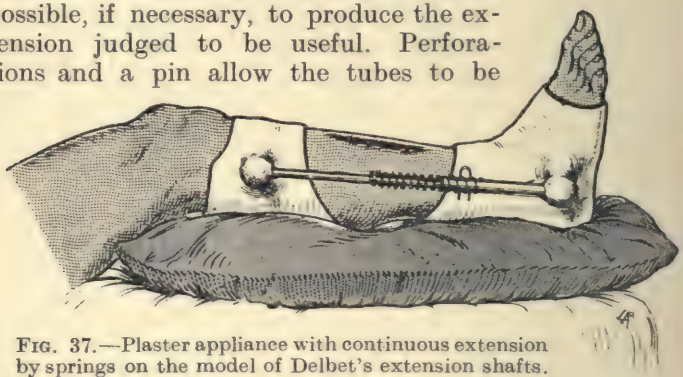


FIG. 37.—Plaster appliance with continuous extension by springs on the model of Delbet's extension shafts.

These continuous extension plasters are far preferable to simple plaster appliances, which usually reduce displacements and deviations unsatisfactorily.

Advantages and disadvantages of, and indications for, Plaster appliances.—The great advantage of the plaster appliance is that it is easily made, and reduces pain by producing admirable fixation, diminishes infection, and makes for recovery.

It is criticised on account of the trouble in dressing

and supervising these wounds which it causes, and its frequent tendency to produce compression and ulceration.

All this is true, but it is all a matter of supervision, and no fracture appliance exists which does not demand a great deal of attention.

Plaster should be employed whenever rigorous fixation is required for a patient who is to be left a comparative degree of liberty ; for this reason plaster is the ideal transport appliance ; lack of time sometimes prevents its use, but it should never be forgotten that for evacuation nothing can take its place. *The best plaster for this purpose is the classical plaster trough well adjusted ;* a postero-external scapulo-metacarpal splint for the arm ; a dorsal humero-metacarpal splint for the forearm ; a dorsal pelvi-pedal splint for the thigh ; and a posterior cruro-pedal trough for the leg.

On the other hand, the plaster trough does not allow of continuous extension, and it is for this reason, in a general way, that it is not advisable except at the beginning and the end of the treatment.

Circular plaster appliances are scarcely suitable except in the third stage, when reduction by extension has already been produced, and union is on the point of commencement or completion.

On the other hand, continuous extension plasters are excellent appliances for the active period of treatment, if it may so be termed.

Interrupted appliances are not often advisable : there has been much misuse of these appliances which so many surgeons suppose they have invented, whereas they had been abandoned for thirty years, and have been recently reintroduced by Gourdet. The very great ingenuity required and displayed in their construction has been one of the factors of their success. They are now being given up, which is only right ; as a means of fixation they have given indifferent results, and they have often served to conceal serious errors

in treatment. They immobilise badly, and soon allow insidious slippings and secondary over-riding, and should therefore be used only for short periods in particular cases, and in definite circumstances—when, for instance, an extensive wound requires to be widely exposed, in a patient who is able to get about.

In fact, if the fracture suppurates, it is not an interrupted plaster appliance that is required, but an operation ; if the wound is large and the patient condemned to bed for any reason, he will do far better with a suspension apparatus ; if the wound is not suppurating and the progress of the case is normal, infrequent dressings allow of a plaster trough being used.

The practice of immediate or secondary sub-periosteal esquillectomy, the aseptic development of the wounds, and the rapid formation of a periosteal callus, allow the necessity for appliances specially designed to facilitate daily dressings to be regarded as unusual : the treatment of gunshot fractures thus tends closely to approximate to that of fractures in time of peace.

2. LIMITED IMMOBILISATION OF THE FRACTURED AREA.—The real solution of this difficult problem is entirely due to Pierre Delbet, who set out to find a means of maintaining reduction without interfering with the movements of the limb. With this object, and to immobilise fractures without fixing the adjacent joints, he invented a series of excellent appliances which may be described as being an extensible external prosthesis, buttressed against the epiphyseal projections of the fractured bone, or other bony projections immediately adjacent to and intimately connected with it.

There are four types : *in the arm*, the appliance takes purchase above from a metal crutch in the axilla, and below from a curved plate on the flexed forearm ; *in the forearm*, below from the lower end of the ulna and the radius, the trapezium and the unciform bone, above from a plaster surrounding the flexed elbow ; *in the thigh*, the points of support above

are the ischium and great trochanter, below a plaster collar around the supra-condylar depressions; *in the leg*, above from the depression beneath the head of the tibia, below from the malleolar prominences.

The leg appliance is a continuous extension plaster; the other appliances are special instruments; those for the arm and forearm may be improvised by simple means; the thigh apparatus cannot be improvised; it is also difficult to apply, and painful if not very well applied.

These remarkable instruments will be discussed in connection with each individual fracture.

3. Fixation by Suspension with Continuous Extension.—This excellent method is being more and more widely applied, a state of things for which Blake is largely responsible. At first it appears complicated; it is actually very simple, but requires a good deal of supervision and careful attention to details.

Though applicable in all regions and easily improvised, it has the disadvantage of confining the patient to bed; for this reason its use in the upper limb has been restricted. It appears the most suitable method for the thigh, and also for the leg in certain fractures.

The principle consists in placing the limb in a hammock suspended from a frame by cords passing over a pulley carried on the frame, and kept in equilibrium by weights, while a continuous pull is applied in a suitable direction.

The sling for the upper limb is represented by two large diamond-shaped slings of soft material, 28 to 32 inches long and 4 inches wide, passing round the arm, one above and one below the fracture. The two extremities of each sling have slits through which the suspension cord passes. The latter passes over a pulley situated on the frame (which will be described later) in a line perpendicular to the fragments of the bone. The cord passes over a second pulley, and

supports a weight exactly counterbalancing that of the arm. The two fragments are thus fixed in suspension; their relative position is maintained in space without injury or friction.

In the forearm, thigh, and leg, the sling is represented by a series of narrow strips of material, stretched on a metal frame consisting of strip iron ·4 inch wide and $\frac{1}{8}$ inch thick. The suspending slings for the limb are 6 inches wide and 20 inches long; they are passed over the metal frame on each side and fixed with safety-pins. This arrangement allows easy inspection of posterior wounds; it is sufficient, in fact, to detach one strip by removing the pin to have access to the part of the limb which it is desired to examine.

FIG. 38.—Suspension apparatus (see figs. 105 and 115).

If the wound is oozing at all, the strip in contact with the dressing may be replaced by rubber or by an aluminium plate moulded on the limb and supported by bending it over the edges of the metal frame: cleanliness is much facilitated in this way.

The four corners of the frame are fitted with small figure-of-eight hooks, to which the suspension cords are attached. The two upper cords unite 20 inches above the frame, the single cord thus formed passing over a pulley placed on the upper frame in a line vertically over the ends of the sling, or at a point slightly beyond it. Beyond this the cord descends, supports a sliding central pulley from which a weight is suspended, and unites with the cord from the lower end of the sling, which is formed in the same way and

passed over a pulley vertically above the lower end of the splint. The centre weight should exactly counterpoise the limb and keep it in suspension (see fig. 115).

I shall explain the exact arrangement in connection with each limb-segment : the above diagram (fig. 38) is sufficiently explicit for the present.

The superstructure is more or less complex according to what it is desired to do. In the most complete model it consists of a double frame, the vertical pillars of which, about 6½ feet in length, are prolongations of the bed-posts, and whose upper horizontal traverses are slightly longer than the bed. These pillars may be made of metal or of white wood. The transverse bars are notched or pierced at regular intervals : these holes or notches are intended to fix or receive longitudinal bars, movable at will, which are placed in line with the bed or with the limb ; they are themselves pierced by a series of holes at regular intervals, upon which pulleys may be hung. The latter are of the ordinary commercial type.

In other words, four vertical pillars support a horizontal frame, along which suspension pulleys may be attached in any direction desired. A perfectly balanced suspension is therefore obtained, which permits movement of all kinds.

In the most simple model, which is quite satisfactory in practice, although rather less convenient, two vertical supports, 6½ feet in length, support a horizontal bar which is placed in the line of traction desired, and from which the necessary pulleys are suspended. One at each end is sufficient ; over these, as has been said, pass suspension cords, which meet beneath a free central pulley supporting a weight.

The weight, which should be 4 to 8 kilograms for the lower limb, is provided by a series of sheets of lead or a bag of sand.

Extension is carried out on the ordinary principles, by means of adhesive strapping. Or again, the pull

may be exerted simply by means of a stirrup of soft material, which is applied methodically to the limb by a bandage. With some practice, perfect continuous extension may be produced in this way.

These appliances possess great advantages: they allow very easy supervision of the wound, the fracture, and of the whole limb; they greatly facilitate the dressing of the wound; they rapidly ease the patient, who is no longer in pain and is able to move in all directions, even to raise himself, and to move the limb very easily and without pain; finally, the suspension of the limb above the level of the bed makes nursing an easy matter, and makes for the physical hygiene of the patient. A further advantage is that they permit small movements of muscles and joints, and therefore favour recovery of function.

C. Choice of a fixation appliance.—It must not be supposed that there is a universal method of fixation, and one appliance which is better than all the rest for each type of fracture. Of the different types studied above, there is not one which is not indicated by particular conditions: to speak very roughly, the trough should be regarded as the temporary emergency appliance; plaster as the appliance for transport and convalescence; while Delbet's apparatus and its modifications, the suspension appliances, as those to be used for treatment.

D. Duration of fixation.—This should be regulated according to the fracture and the patient. In general, fixation is rarely too prolonged. Fixation, it is true, is severely criticised; it is made responsible for stiffened joints, muscular atrophy, and trophic disorders of the skin. But it is far from being proved actually to cause these, and its disadvantages are enormously exaggerated. When all is said and done, the advantage, from a local point of view, in allowing a case of fracture to walk too early is certainly not very great. The violence of the original injury, per-

sistent infection, and faulty reduction are the real causes of permanent loss of function; fixation prolonged for two or three months leads to no serious persistent trouble if the wounds are not septic. Immobilise a case of gonorrhœal arthritis for three months or a tuberculous joint for eighteen, and when the patient has recovered, the neighbouring joints will rapidly redevelop free play. If it is otherwise after a fracture, there is a local cause—distant osseous contusion, the formation of fissures, etc. In any case, the therapeutic method is not responsible.

After sub-periosteal esquillectomy, *even when the callus appears, both clinically and by X-rays, to have formed* (after forty to fifty days for the upper limb, sixty to eighty days for the lower), *fixation should be prolonged for a further twenty days at least, since the callus is not always very firm, and may become bent secondarily*. It is at this time that walking appliances should be used.

It should be considered a definite rule that sixty days' fixation is necessary for the upper limb, and eighty to a hundred at least for the lower.

E. Delayed consolidation.—If consolidation has not occurred at the end of this period, there is reason for adopting mercurial treatment (local dressings with calomel ointment), and for giving a little iodide. This often produces the desired result in a few days.

If there is no result, the surfaces of the fracture may be scraped with a curette. I have once seen a callus form very rapidly after this instrumental irritation.

Lastly, if everything has failed, I advise the immediate introduction of a metal suture, without waiting until the end of the period which is stated to elapse before pseudarthrosis * can be said to have

* Very recently in a fracture of the humerus after secondary esquillectomy which did not consolidate, I introduced a metal suture on the ninety-second day: at the first dressing, ten days afterwards, the callus had formed.

occurred, and particularly without waiting, as is the usual practice, for the wound to heal completely.

F. Treatment subsequent to immobilisation.—Massage, hot water, hot air, passive and active movements, should be introduced as early as possible. On the other hand, mechanotherapy is usually dangerous, and should not form part of the later treatment of fractures.

CHAPTER III

FRACTURES OF THE HUMERUS

From the point of view of treatment, there are four types of fracture of the shaft of the humerus :

Fracture of the neck of the humerus ;

Sub-deltoid fracture ;

Fracture of the middle of the shaft ;

Supra-condylar fracture of the elbow.

These are obviously rather rough distinctions ; there are many types that are intermediate between these, but typical cases are still the more numerous, and in each of the groups mentioned there are characteristic peculiarities, which demand a special method of applying the general rules for treatment outlined in the previous chapter.

I. Fracture of the Neck of the Humerus (Sub-epiphyseal Fracture)

1. Anatomical Features.—In the most typical cases, the direction of the fracture is transverse. It is clearly extra-articular at the level of the neck of the bone or immediately below it. The upper fragment, including the head and the tuberosities, is often prolonged down the front and outer side of the bone by a splinter of some length formed from the external face of the shaft at some distance from the biceps tendon, which remains intact on its inner side, or is torn away by the violence of the injury.

Fissures are very often found in the lower fragment,

and there is almost invariably severe injury to the cancellous tissue of the head of the bone. The cartilage is sometimes cracked, or even split clean across.

A greater degree of injury is the crushing of the epiphysis and shaft, dealt with in Vol. I (p. 35).

There are no large or adherent splinters; on the other hand, large numbers of small bony fragments are found, with a quantity of bone dust, which the injury scatters amongst the muscles over the prominence of the shoulder.

When the missile enters or passes out through the posterior region of the shoulder, at the level of the axilla, the circumflex nerve may be involved; the radial (musculo-spiral) is more often injured as it passes out of the axilla: the two ends of the nerve retract in opposite directions, and subsequent repair is always difficult and may be impossible.

2. Physiological Features.—Displacement of the upper fragment is caused by the muscles connecting the scapula with the tuberosity (supraspinatus, infraspinatus, and teres minor). As a result of their action, which is more powerful than that of other muscles inserted into the tuberosities, the upper fragment is abducted and externally rotated, that is to say, the head of the humerus gets out of contact with the glenoid cavity, and, with its cartilaginous surface downwards, rotates in the joint cavity, which is enlarged by expansion, and often lacerated at some point.

If the upper fragment includes the external splinter from the shaft to which I have referred above, this points backwards, and, entering the deltoid, threatens to pierce the skin.

On the other hand, the lower fragment, adducted by the latissimus dorsi, coraco-brachialis, and pectoralis major, and pulled upwards by the deltoid, assumes a position deep to the coracoid process. There is, in fact, very wide separation and displacement of the fragments.

3. Clinical Course.—There can be no question of the case running a course that does not require any surgical intervention : without operation infection is prone to cause the development of gas gangrene (since there are severe muscular lesions), osteomyelitis, or arthritis. Arthritis is almost unavoidable, in the first place because the infected bony region is in immediate contact with the joint, also because there are often fissures in the head of the bone which carry infection nearer and nearer to the joint cavity, and lastly because osteomyelitis of the upper fragment passes gradually upwards, and infection of the joint occurs after a few days through the ulcerated cartilage. I possess a specimen showing this last method of spread very clearly.

It is therefore always necessary in practice to intervene in order to prevent rapidly fatal complications.

What becomes of the fracture after an early operation ?

Let us suppose a minimum degree of intervention, a *falsely conservative* operation (*i.e.* an attempt, which is ultimately unsuccessful, to preserve as much of the injured structures as possible) which is limited to the removal of the missiles, cleaning the approaches to the actual region of the fracture through the wound of entry or exit, removal of free splinters which the forceps happen to encounter, in a wound accessible with difficulty, *because nothing further appears at the moment to be necessary*. Let us suppose even a rather more comprehensive operation, which deals with the bony area, cuts off the sharp point of the upper fragment, and passes a drainage tube through the region : the prevention of serious and rapidly fatal sepsis is realised in this way, but chronic osteomyelitis will be unavoidable, the wound will suppurate profusely, and the joint will probably be invaded, owing to its contiguity.

This persistent septic condition will render it very

difficult, if not impossible, to achieve even an approximate reduction which will necessitate the extremely inconvenient fixation of the lower fragment in line with the upper, that is to say, elevation of the arm above the horizontal in a position of abduction and external rotation. It may therefore be supposed *a priori* that the reduction will be bad, and, as prolonged suppuration in a subepiphyseal region, where the periosteum is weak and thin, is always likely to cause pseudarthrosis, and also since there is often some muscular interposition, there will be every reason to expect a deplorable result.

FIG. 39.—Radiograph of a subepiphyseal fracture of the head of the humerus, six months after the wound was received; treatment was limited to cleaning the soft parts and passing a drainage tube through the fractured area. Fœtid suppuration persisted, with very bad general condition, albuminuria, etc. I removed the head of the bone by the classical method; it was completely free and necrosed, with the cartilaginous face downwards, in an enlarged articular cavity full of pus. (See fig. 44.)

In fact numbers of cases, treated by inadequate methods, which escape the serious consequences of suppurative arthritis and juxta-articular osteomyelitis, are in a lamentable condition at the end of six or eight months; the head of the humerus, separated from its vascular connection with the shaft, becomes rarefied and almost translucent under X-rays; fœtid pus escapes through two or three sinuses, bulky periarticular callus produces a kind of circular ankylosis,

isolating the head of the bone, without producing satisfactory bony union between the epiphysis and the shaft.

To cure these unhealthy, wasted, sallow patients, a late secondary resection is required, the functional gain of which is necessarily very poor, since the muscles have become adherent and all the tissues round the joint are sclerosed and rigid. Totally different action must therefore be taken.

4. INDICATIONS FOR EARLY TREATMENT.—*Fracture of the neck of the humerus should be treated early by typical sub-periosteal articular resection.* As soon as the diagnosis is confirmed by X-rays or by an exploratory incision of the exit wound, the *classical resection* should be carried out.

The joint is exposed by a rather low antero-internal inter-deltoid incision; the capsule being opened with a bistoury, the rest of the operation is performed with the cutting rugine (see Vol. I, p. 23).

Generally the intra-articular damage which will be found, and which the radiograph did not indicate, will cause surprise: the fissuring of the cartilage mentioned above will almost always be seen; often one or two small osteo-cartilaginous fragments will even be found free in the joint cavity.

The head of the bone is gripped by strong forceps and pulled outwards, while the sharp rugine carefully separates the periosteum and the capsule round the anatomical neck near the tuberosities and along the shaft splinter, if one exists.

There will be often some difficulty in gripping the head of the bone, which is no longer in contact with the glenoid fossa, but lower down and within an enlarged synovial cavity.

The lower fragment is thoroughly exposed and examined, and gently cleaned with the curette, or if necessary, trimmed with bone-cutting forceps.

The operation is concluded by careful cleaning of

the soft parts, excision of all loose muscular débris, and removal of any small splinters buried in the muscles.

The wound is left open; a drainage tube placed in the glenoid cavity passes out through a posterior counter-incision at the seat of election (see Vol. I, p. 52). The anterior incision and the wounds of entry and exit are loosely plugged with gauze.

Fixation is ensured by a bandage binding the arm against the body; the case is then conducted like one of resection for articular fracture.

Advantages of this method.—No doubt this procedure will appear drastic: at the front, some surgeons will say that in the early stage it appears too drastic, since a restricted operation, ostensibly more conservative, is sufficient to prevent serious developments due to infection, to obviate disarticulation, or to prevent death; at the base, others will recall rare cases in which cure was effected with little trouble.

Neither, however, should forget that among the cases of this sort that they have seen there have been rapid deaths from gas gangrene, osteomyelitis, and acute arthritis, that an emergency operation for resection of the joint has sometimes become necessary on the third or fourth day, when the operation on the fracture had been performed only twenty-four or forty-eight hours previously; lastly, that numbers of cases evacuated still persistently suppurate, eventually requiring an extensive operation after months of suffering and repeated drainage.

In fact, the record of incomplete operations is frankly a bad one; these are the operations claimed to be conservative on the strength of a few fortunate cases which are rendered more prominent since the failures (deaths, disarticulations, etc.) are no longer there to darken the prospect.

Does early excision give better results? Decidedly.

It invariably prevents serious septic phenomena;

after it there are neither deaths from uncontrollable sepsis nor secondary disarticulations; under careful treatment *all* cases recover in a short time (forty days to two months). This is the first important reason, sufficient to prove that *intervention is truly conservative*. It has the disadvantage of removing too large a quantity of bone for function to be as well preserved as it may be after excision limited to the epiphysis.* But this does not mean that its results are bad. To appreciate them, conclusions should not be drawn from the very mediocre results of late excision. There is, in fact, from this point of view, a vast difference between these and excisions in the earliest stages; the latter, correctly performed, preserve the innervation of a healthy deltoid; asepsis having been achieved, all the muscle not directly involved in the original injury remains intact, and does not undergo permanent sclerosis; this muscle, moreover, actually retains its original action, since its origin and insertion are preserved. The rapidity of the cure allows massage and electrotherapy to be begun early, with the result that at the end of three or four months regular active exercise is possible. Further, if the operation has left the capsule and periosteum intact, ligamento-periosteal continuity is obtained, which has a great effect on the functional conditions, even if extensive regeneration does not occur. Owing to this, cases in which resection has been performed regain a very satisfactory use of the limb; the arm is certainly not rigidly fixed, but contraction of the shoulder muscles allows of fixation of the humerus; it is pulled upwards into contact with the glenoid cavity, and in that position the elbow can be abducted and the arm raised more or

* To judge the functional results of excision of the shoulder, it is essential to distinguish between resections limited to the epiphysis or joint, and those involving both it and the shaft. This distinction has not always been drawn in works which condemn excision in wounds of the shoulder as giving bad results.

less towards the horizontal, either outwards (action of the acromial fasciculi of the deltoid), forwards (action of the clavicular fasciculi), or backwards (action of the scapular fasciculi). Given the usual laceration of the muscle at some point, these three movements are not realised, so to speak, in perfection, since the combination requires an absolutely intact deltoid, but the arm is really active, and does not merely hang against the body, as in a case where the deltoid is paralysed by the original injury or a careless incision severing the circumflex nerve, or has been practically destroyed by prolonged suppuration.

It will perhaps be said that this optimistic picture does not correspond with the reality. It is certainly a picture of the favourable results only to be obtained by the correct operation on a vigorous subject, and by well-directed subsequent treatment. But account must be taken of cases of weaker physique, in which the operation and subsequent treatment have been technically faulty : excision of the head of the humerus performed at the front by the sub-capsulo-periosteal method demands careful attention from the surgeon in charge at the base hospital, and not the incomprehensible indifference, a justification of which is attempted by speaking later of the bad results of the excision. Cases in which I have carried out both the operation and the subsequent treatment until cure was complete have always given very satisfactory results. I recently looked after a case upon which Gayet and Truchet had operated, in which the functioning of the arm is remarkable, in spite of the loss of $3\frac{1}{2}$ in. of the bone. All the movements of the humerus can be performed to two-thirds of their normal extent.

Further, the worst results may often be bettered by humero-scapular ankylosis, by repair of the scapular muscles, or by an artificial appliance.

This discussion may be summarised in the following way : in sub-epiphyseal fractures, a solid callus with

ankylosis of the shoulder-joint and without a sinus is better than the result given by an extensive resection, but there is never any certainty of obtaining this favourable result ; a great risk is run, when the latter is expected, of attaining nothing, and resection is the only absolute guarantee against disaster. For this reason resection is in reality the truly conservative treatment : the average of results obtained by early resection *well performed* is very satisfactory ; having regard to the seriousness of the lesions, it is decidedly perferable to what one can obtain in any other way, provided always that the operation is undertaken early, and that it leaves the musculature intact ; sometimes its results are remarkable.

5. The Treatment of cases already under Treatment or seen at a late stage.—Four types may occur :

(*a*) *A case progresses well after a restricted operation confined to the fractured region and its immediate surroundings.* Every effort should be directed towards securing fixation in a good position. After X-ray examination, a plaster appliance is fitted, so as to fix the limb in a suitable position, that is to say, bringing the lower fragment in line with the upper. A plaster bandage should be used, and an opening made where the wounds are situated. If one of these is large, a bracketed interruption may be fitted, but the ideal arrangement for wounds which suppurate little or not at all is a plaster bandage round the upper limb and a plaster jacket, which ensures the best possible immobilisation.

For this purpose, the trunk is covered by a vest or by gauze padding, and a jacket is made by means of plaster bandages. It is useless to incorporate splints ; two or three bandages 5 yards long are enough to cover the chest with a moderately resistant casing, moulded over the shoulders and clavicles. When its thickness is considered suitable, a few figures-of-eight

are carried round the axilla, the strapping being passed from the shoulder on to the upper limb, and then down the arm and forearm as far as the metacarpus. The arm is fixed in abduction, the elbow being at some distance from the trunk, the forearm flexed in semi-pronation, and the thumb directed upwards.

FIG. 40.—Plaster with a window-opening.

When the upper limb is entirely covered by three regularly wound bandages, and as soon as the plaster has dried, openings are cut with a bistoury which will suitably expose the wounds. There need be no hesitation in making an opening sufficiently wide for the plaster not to be soiled; pads are slipped under the edges of the opening to prevent their disintegration, and an opening is cut to free the lower borders of the axilla.

This appliance is worn for about a month. At the end of this period, healing will generally be complete. The union of the bone is tested, and if it has occurred, the restoration of movement is begun.

If the wounds are more extensive, and require openings so large as to be incompatible with the solidity of the appliance, a bracketed plaster appliance should be used. This is constructed according to the fundamental rules of fixation, that is to say, it will fix the trunk and the elbow. That the arm may be well

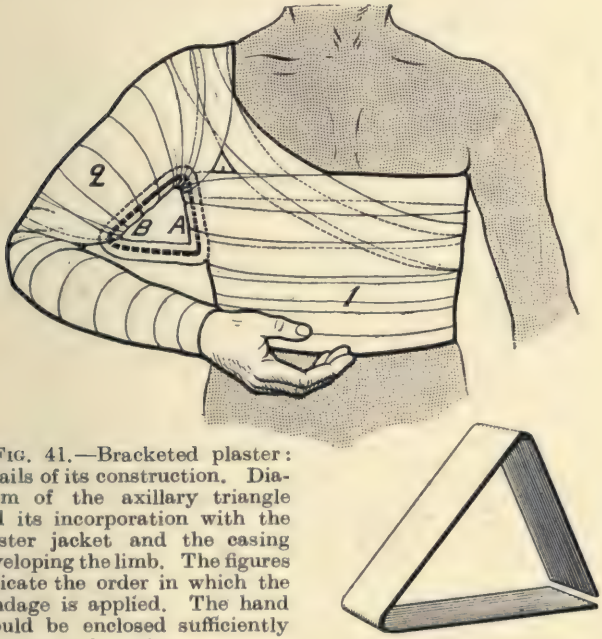


FIG. 41.—Bracketed plaster: details of its construction. Diagram of the axillary triangle and its incorporation with the plaster jacket and the casing enveloping the limb. The figures indicate the order in which the bandage is applied. The hand should be enclosed sufficiently to support the wrist.

sustained by a solid support, a metal triangle is placed in the axilla, made with a strip of metal bent in two places, or with any other rigid supporting material. Each side of this triangle is 6 to 7 inches long.

The appliance will include:

(i) A plaster jacket firmly enclosing the injured shoulder, made with three or four five-yard bandages.

(ii) A circular bandage enclosing the limb from the shoulder to the distal extremity of the metacarpals (three bandages).

(iii) A triangle of sheet iron, padded with wool fixed on with a gauze bandage.

(iv) An iron loop in the form of a bridge. This loop, the ends of which are slightly raised in order to pre-

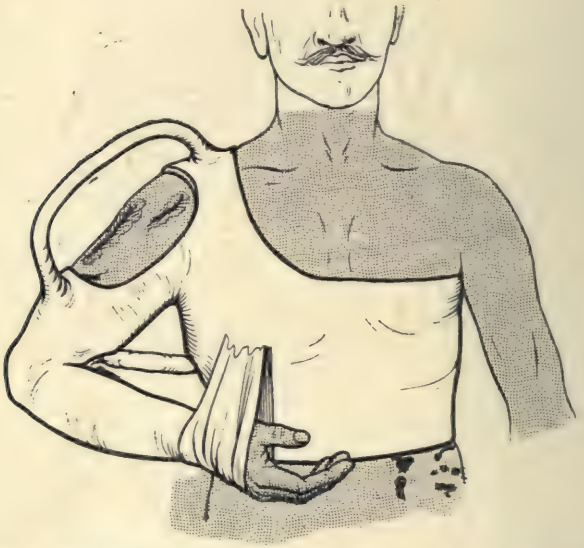


FIG. 42.—Bracketed appliance complete; a sling supports the forearm and hand.

vent slipping, is supported, above, beyond the coraco-acromial arch on the line from the shoulder to the neck, and below, at a point on the casing of the arm immediately below the wound.

The plaster jacket is applied first, the bandage passing over and including the thoracic side of the axillary triangle. When the latter is well fixed, the bandage is passed over the shoulder, and describes figures-of-

eight round the axilla and the neck, then is wound round the arm, binding the humeral side of the axillary triangle to it. This done, the enveloping of the elbow, forearm, and hand is carried out, these structures being fixed in the position already indicated.

Finally, the scapulo-humeral bracket is fixed in place on the plaster by another bandage, and nothing

FIG. 43.—Radiograph fifteen days after extensive sub-periosteal resection of the shoulder done on the fourth day in a case of extensive injury to the epiphysis and shaft. The outline of the capsule and periosteum of the head is clearly visible.

FIG. 43*a*.—Radiograph of the same case four months after resection: complete cure was obtained in two months, without pyrexia at any time. The satisfactory regeneration of bone in the injured region will be noticed. The functional result is excellent.

remains but to expose the region of the wounds and to trim the edges of the plaster.

(*b*) *A case arrives in a more or less septic condition, suppurating profusely, or with local signs of arthritis of the shoulder-joint.* Immediate sub-periosteal resection is necessary. It is certainly possible, by suitable incisions, to provide sufficient drainage to arrest the general symptoms, but it is impossible to

prevent slow necrosis of the head of the bone, which is becoming isolated in the articular cavity. Its removal should not be delayed until muscles have been destroyed and the patient's general condition is bad.

This late secondary resection is necessarily more drastic than if it had been done immediately, since the end of the shaft is also usually diseased. The functional result varies inversely with the muscular injury ; if the musculature is still adequate, remarkable functional recovery may occur (figs. 43 and 44). The regeneration of bone is also almost always very complete, if care is taken to preserve the periosteum.

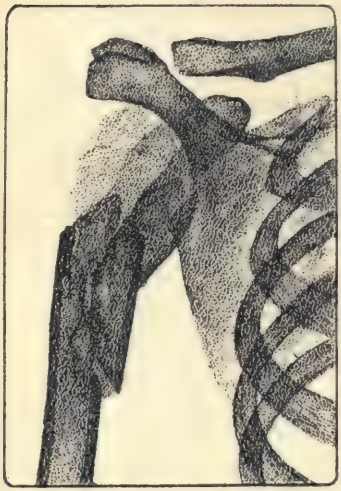


FIG. 44. — Radiograph four months after late sub-periosteal resection, in the case illustrated in fig. 39. A large bridge of bone formed from the periosteum unites the shaft with the glenoid cavity, and the shoulder is ankylosed. I did not attempt to restore movement on account of the complete disorganisation of the muscles.

(*c*) *A case arrives with sinuses.* The first step is an X-ray examination which will show accurately the real condition of the upper extremity of the humerus and the joint. In a few exceptional cases, union will have occurred, the joint will have remained free, and the only trouble will be superficial osteitis, with or without sequestra. Treatment should be limited to scraping the bone clean and removing sequestra.

But more often there is no callus and the fracture is suppurating, there are numerous dead splinters in the neighbourhood and in the joint, and the upper fragment

is obviously inflamed. Resection is necessary; the usual incision is made without regard to the position of the sinuses. Every effort is made to preserve the periosteum as completely as possible. It will often be necessary at the first dressing to sacrifice the biceps tendon, which is gangrenous and giving rise to suppuration.

(*d*) *A case is seen with pseudarthrosis.* Sometimes there is but little functional trouble, and there should be no interference, treatment being directed to development of the muscles. In other cases there is considerable trouble: if sepsis is not clinically evident, if the upper fragment is prolonged downwards by a splinter from the shaft, and if the joint is free, osteo-synthesis may be attempted after trimming of the fragments, but the operation is difficult to carry out and the result doubtful. If this intervention is not attempted or has failed, a prosthetic appliance must be used.

(*e*) *A case is seen with a flail-arm.*—It will be understood that there are two categories of flail- or useless arms: the active form in which the upper limb swings freely in repose, but can be fixed by muscular contraction when a movement is to be carried out, and the passive form in which the whole upper limb hangs absolutely useless.

The active flail-arm is, in fact, what it is attempted to produce by excision of the head and part of the shaft. The result is generally satisfactory, often remarkably so, even after extensive resection (fig. 43*a*), and there is no occasion for interference.

On the other hand, a passive flail-arm is a serious infirmity, which not only destroys the function of the shoulder, but greatly interferes with that of the forearm and hand. Contrary to what is usual in the elbow, it is not always possible in this case to redevelop by prolonged massage sufficient muscle to support the arm. Recourse should then be had to

the use of a prosthetic appliance, which gives a very fair result.

Attempts may also be made to improve the situation by effecting humero-glenoidal fixation, humero-clavicular suspension, or the double humero-coraco-acromial suspension which Ollier practised.

I have no experience of these and cannot say what is actually effected. But according to the fullest information I possess, I believe this solution infinitely preferable both to any grafting that the surgeon might be tempted to effect (graft from the fibula) and to osteoplasty by reduplication of the humerus, which is technically much more difficult and apparently less reliable in its results.

II. Sub-deltoid Fracture

1. Anatomical Features.—This is a fracture situated in the upper third of the humerus, of such a nature that the lower fragment of the shaft is absolutely or nearly intact, below the insertion of the deltoid. The fracture is often comminuted; the shell-fragment or bullet has, as it were, entirely removed the bone below the insertion of the muscle, with the result that the deltoid acts unrestrainedly on the upper fragment.

In other cases there are large, very oblique splinters, but this is less common.

As a rule there are no radiating fissures or accompanying vascular and nervous lesions.

2. Physiological Features.—The deltoid pulls strongly on the upper fragment and abducts it; its lower end is thus found to be raised and deflected outwards, with the medullary canal directed outwards, while the lower fragment remains in place, embraced by the brachialis anticus. The angle formed by the two fragments, which is about 45°, is incomplete on

its inner and posterior aspect; it is here that small fragments and bone dust are found.

In some fractures the opposite displacement occurs, the upper fragment being pulled strongly inwards and internally rotated (fig. 46). This displacement is due to partial laceration of the deltoid insertion, giving predominance to the action of the pectoralis major; this muscle then pulls the upper fragment into a position such that fixation should be effected with the elbow and arm made fast to the trunk, and vertical extension by weights as indicated in fig. 60.

FIG. 45.—Low sub-deltoid fracture: the position is usually higher in the shaft.

3. COURSE. — Infective lesions here are similar to those met with in any other region; what, however, characterises this fracture is the impossibility of manual reduction; the angulation of the principal fragments persists indefinitely, if it is not corrected by placing the lower fragment, which alone can be moved, in direct line with the upper. Pseudarthrosis sometimes results, particularly in comminuted fractures and when the wound suppurates; the infection then destroys the activity of the periosteum which alone can produce material to bridge the gap.

When, on the other hand, the infection is slight (in fracture by bullets causing only small cutaneous wounds), union occurs, but with marked deformity (antero-external angulation) and marked shortening.

4. INDICATIONS FOR EARLY TREATMENT.—Sub-periosteal esquillectomy is necessary here as elsewhere in order completely to prevent sepsis; the thick muscular layer surrounding the injury makes the danger of the development of serious infection in a closed cavity very serious.

In performing the operation, the fracture should preferably be approached by an antero-internal incision, the muscle fibres being separate in order to reach the bone; a posterior incision might result in severance of the circumflex nerve, and therefore in permanent paralysis of the deltoid, which should be avoided. The entry and exit wounds should be cleaned, but drainage is carried out through the incision. Bone débris should be removed with minute care, the muscle being often riddled with it. In this, however, there is nothing peculiar.

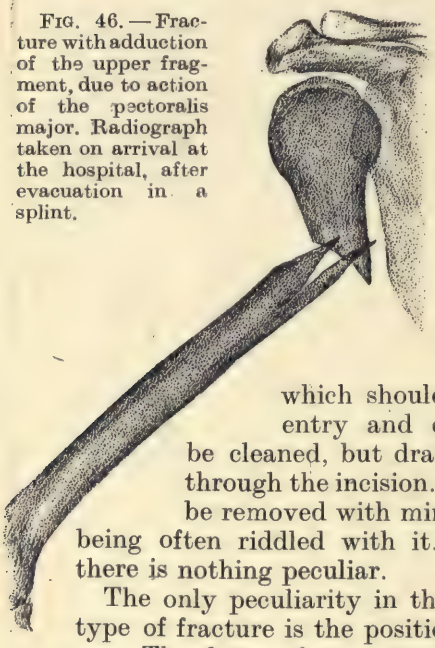


FIG. 46.—Fracture with adduction of the upper fragment, due to action of the pectoralis major. Radiograph taken on arrival at the hospital, after evacuation in a splint.

The only peculiarity in the treatment of this type of fracture is the position in which it is put up. The lower fragment, which is movable, whereas the other is not, is brought upwards and outwards into line with the upper fragment, and the arm is immobilised in this position.

This can best be done by means of a plaster apparatus constructed in one of the following ways, both of which I have employed several times.

(*a*) *If the wounds are large.* The appliance should

leave the arm exposed, merely supporting the lower fragment in line with the upper. This plaster consists of five pieces :—

(i) A thoracic belt which is applied first.

(ii) Two braces, one as broad as the palm of the hand, and passing over the uninjured shoulder; the

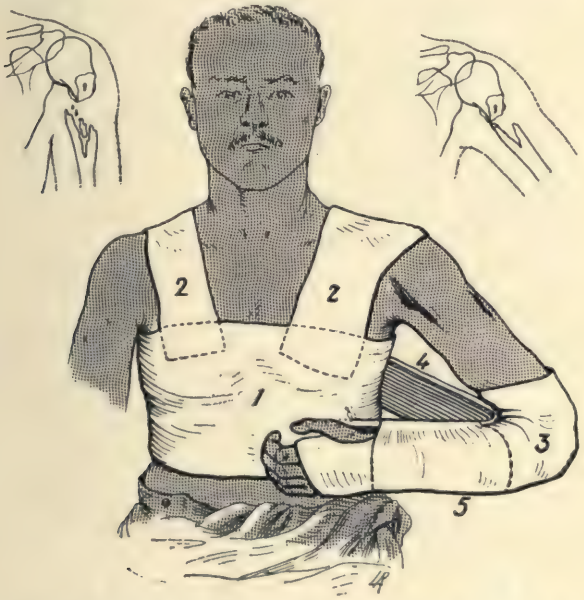


FIG. 47.—Plaster apparatus for immobilising the arm in an abducted position. The two small sketches are copies of radiographs taken before and after application of the apparatus in the particular case illustrated. The figures indicate the order of application of the different pieces of the appliance.

other much wider in its centre where it covers the injured shoulder.

(iii) A trough for the forearm, embracing the elbow and passing some distance above it. A plaster bandage is wound round these different pieces to unite them.

(iv) A metal splint (*e.g.* a small wire splint such as is found in the field-service outfits) bent at an acute angle in the middle, which is incorporated horizontally in the chest plaster by means of a plaster bandage (figs. 47 and 48). Its object is to support the lower fragment in the position of abduction.

FIG. 48.

For the first few days three or four wooden splints are fixed by strapping over the dressing, to secure better immobilisation of the fragments, as is shown in fig. 60.

This excellent appliance is kept in place until union occurs. If it should deteriorate, another of the same type is made, or the appliance described below may be employed.

(*b*) *If the wounds are not extensive*, an apparatus is made with plaster bandages in the following way :

A well-fitting plaster jacket is first made, covering the injured shoulder (three or four bandages 5 yards in length), then one is made to cover the upper limb, supported in a position of abduction.

To maintain it in this position I used to consider a bent iron loop necessary, surrounding the elbow and fixed to the thorax. For some time I have replaced this by a sort of plaster bridge, made of several thicknesses of bandage, and kept stretched between the elbow and chest by an assistant until it has set.

A few turns of a plaster bandage make this bridge solid and unite it with the rest of the appliance ; it is much lighter when made thus.

It is safer to include a second plaster support connecting the elbow with the lower edge of the jacket (see fig. 49).

A rigid axis of wood or cane can be incorporated

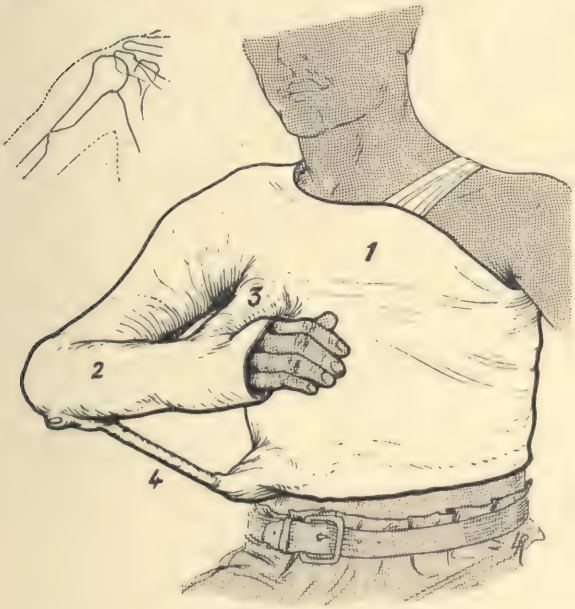


FIG. 49.

with great advantage in the two plaster bridges : an ordinary ruler makes an excellent support. It is also possible to use the arrangement described on p. 117.

If the patient has to be kept in bed, the best method is the suspension appliance which will be found described in fig. 65, p. 152, traction being exerted in a position of abduction, which is easily arranged.

5. INDICATIONS IN CASES ALREADY UNDER TREATMENT OR SEEN AT A LATER STAGE.—(*a*) *An evacuated case in which esquillectomy has not been done is going on well at the end of five or six days.* If there is no infection, no suppuration, and no foreign body present, it is only necessary to immobilise the limb in a good position.

(*b*) *A case, in which there has been an incomplete operation, or none at all, is still suppurating profusely when seen during the first three weeks.* After X-ray examination, by which the position and features of the lesion are determined, free esquillectomy and drainage is carried out, and the limb is immobilised as after a primary operation.

(*c*) *A case is found to be suppurating, but union is beginning.* An operation on the bone is probably inadvisable. The best course is merely to drain and remove free splinters, but it is not the time to interfere with adherent splinters and to injure the infected bony area; at this stage any course that is in the least drastic is dangerous. It is better to wait for the later stage of sinus formation, when the patient's condition is less feeble probably because the medullary canal has become shut off.

(*d*) *A case is seen with a sinus.*—This is almost always due to a free splinter, which is more or less enclosed and unable to escape. There is rarely a central sequestrum, and the operation is generally easy.

(*e*) *A case is seen with pseudarthrosis.*—This is almost always due to want of reduction, and the condition justifies forcible reduction with metallic osteosynthesis by Lambotte's method or by wiring.

III. Fracture of the Middle of the Shaft

1. ANATOMICAL FEATURES.—Of all the fractures of the upper limb, these are the most frequent.

Two principal types exist, that accompanied by large

splinters and that marked by small splinters; each of these exhibits the general features discussed on p. 5.

In the large-splintered type, which appears more common than the other, there is either roughly the butterfly-wing arrangement described by military surgeons, or extensive lateral splintering, opening the medullary canal and impossible to describe owing to its variety (fig. 5); often in this case, the missile, being spent, stops in the medullary canal; the majority of the splinters are originally adherent and fixed, but free particles of bone are constantly found in the medullary canal.

In the comminuted type, nearly the entire segment of bone injured is shattered into débris and projected into the muscles, or left as adherent splinters rotated upon their own axes: the largest fragments are scarcely more than 2 inches long, and they are the least numerous; in fact, little is left between the two fragments of the shaft, and the actual gap is almost always about 2 inches wide.

The peculiarity of these two types is the extreme frequency of nervous lesions, and particularly of radial (musculo-spiral) paralysis. It is difficult to give an exact figure, but this complication is found in one out of four cases, if not in one out of three. The nerve is most usually severed, and, to judge by my own observations, generally in the classical position, that is to say, in the musculo-spiral groove.

Paralysis of the median, or of the ulnar, or of both, may also be found.

The nerve injury is sometimes a complete severance, sometimes lateral laceration, sometimes simple contusion with interstitial hæmorrhage.

In a number of cases there is associated injury to the lung, the same projectile having fractured the humerus and passed into the thorax.

2. PHYSIOLOGICAL FEATURES.—In comminuted frac-

tures there are none ; owing to the extensive destruction of bone and rupture of surrounding muscles, little displacement of the fragments occurs.

In large-splintered fractures it is unusual for the upper fragment to tilt forwards (action of the deltoid) and perforate the brachialis anticus. This only occurs in the high fractures studied in the preceding section. On the other hand, the lower fragment is pulled up by the triceps and has a slight tendency to backward and upward displacement ; this upward movement is often scarcely perceptible, and a more prominent feature is angulation with its apex pointing backwards. A single radiograph is not sufficient to make this out ; the topography of a fracture can only be appreciated from two plates, one lateral, one antero-posterior. In any case, however, the displacement is slight, the fragments, enclosed by the brachialis anticus, remaining in place.

3. Course.—We will put aside grave and rapidly developing sepsis, causing death from gas gangrene, or necessitating early amputation for acute osteomyelitis. A few uncommon fractures * are seen at the base, which run a simple course from first to last without operation, in which the shell-fragment traversed the bone without leaving anything behind it : such cases are exceptional.

After an operation reduced to what is strictly necessary to prevent the most serious septic phenomena, persistent suppuration generally follows, with purulent tracks along the biceps and brachialis anticus. The local development of suppuration necessitates repeated drainage ; repeated searches are necessary for dead splinters, which make their way towards the orifice of the wound, and the patient, after fifteen or

* I remind the reader that fractures by a bullet which has caused "punctiform" cutaneous wounds are not within the scope of the present study, and that in such cases an uneventful course leading to satisfactory union, after fixation and extension, is the rule.

eighteen months, shows with pride and satisfaction all the pieces of bone which have been removed from his wound.

At the end of two or three months of suppuration the fracture may be in one of the following different conditions :

(*a*) *Consolidation and complete healing.*—If continuous extension has been well effected, reduction is generally satisfactory and the anatomical result is good ; physiologically, the power of the functional muscles is more or less reduced by inflammatory sclerosis and a long period is required for the re-establishment of their normal contractility, but the final result would be very passable if the callus were not large, and often misshapen : it is almost always a badly formed callus, bearing traces of the infected medium from which it has been developed. This is not without importance ; when an operation is performed in the immediate neighbourhood of the fracture with the object of freeing or suturing the radial nerve, all the tissues round the bone are found to be lardaceous and fibrous ; often in dissecting the nerve on the surface of the bone, small superficial osseous cavities are opened, enclosing a small sequestrum surrounded by more or less serous but not virulent pus. The whole region gives the impression of pathological tissues of poor quality. In fact, recurrent fractures are not unusual ; it would, indeed, be surprising if they were.

Briefly, an apparently good result, but with every chance of trouble in the future.

(*b*) *Consolidation with superficial osteitis.*—After five or six months there remains a small sinus covered by a superficial scab and continually oozing small quantities of sero-purulent fluid. It is customary to wait for this to heal of its own accord. I have seen several which persisted for fourteen, sixteen, or eighteen months, and in the majority of cases, associated radial

(musculo-spiral) paralysis had been left without intervention because the wound was not aseptic. Usually a small area of superficial osteitis is concerned, or a small marginal cavity enclosing a sequestrum which cannot escape. Cure can usually be effected by a simple operation.

(*c*) *Union by a redundant callus with a central cavity.*—This is the typical case of pathological consolidation described on p. 26. Passing through the thick periosteal bone, a sinus leads into a cavity, at each end of which is a mass of condensing osteitis closing the medullary canal. The lesion is not spontaneously curable, and is difficult to cure by operation. The prospect for these patients is poor, and the surgeon should not be sanguine of functional recovery. There is every likelihood of frequent outbreaks of sepsis necessitating successive operations.

(*d*) *Pseudarthrosis.*—The absence of union (as apart from its delay) occurs in two conditions, in each by a different process.

In comminuted fractures, in which a segment of the shaft has been pulverised, the marrow is destroyed, and the periosteum very nearly so. Unless asepsis is assured, the remains of the bone-forming tissue on the under surface of the periosteum is destroyed by the infection: rarefying osteitis develops in the ends of the shaft, a certain amount of fibrous and lardaceous tissue becomes interposed between them, and no spontaneous fusion is possible. This is pseudarthrosis by destruction of the tissues which should effect repair.

In large-splintered fractures it often happens that when the appliance is fitted, the splinters which have been left in place, closing in on the long axis of the bone as a result of continuous extension, enclose a more or less isolated fragment of muscle which becomes interposed between the fragments of the shaft, and mechanically prevents spontaneous repair. At the

same time the marrow is destroyed by infection, the periosteum is rendered inactive, and the ends of the shaft undergo necrosis. In a case of this kind I was able to remove a piece of bone which demonstrated this very well. It was built up in the following way: in the centre was a piece of the brachialis anticus ⅓ in. in length, caught below on a sequestrum completely covering the soft and spongy lower end of the shaft, and surmounted by another semi-annular sequestrum covering the upper extremity of the shaft, which was also the seat of rarefying osteitis.

These two types of pseudarthrosis are not of rare occurrence, and the majority seen at the base are of this kind; it is wrongly concluded that the humeral periosteum is comparatively non-fertile. The fact of the matter is that amputation is less frequently performed for fractured humerus than elsewhere since the phenomena of sepsis are less serious in the humerus than in the thigh where the muscular covering is much thicker, and also less severe than in the forearm and leg, where the presence of tendons and their sheaths may lead to serious secondary complications.

4. Indications for early Treatment.—There is only one way of assuring a sure and regular course towards a definite, anatomically and physiologically perfect, cure and of preventing all the troublesome developments described above: that is to perform free sub-periosteal esquillectomy as early as possible. This prevents the development of any signs of infection, and thoroughly clears the bony surfaces. Perfect reduction of the fracture is thus facilitated, without allowing the slightest possibility of muscular interposition; at the same time all the elements necessary to repair are preserved in the wound.

When this operation is carefully performed in the correct manner, that is, with the sharp rugine, the constant result is permanent asepsis; this facilitates fixation of the fracture in simple appliances by which

reduction is easily effected by continuous extension. The three stages of treatment, preventive disinfection, reduction, and fixation, are carried through without hindrance; the patient may be evacuated very soon, and union occurs rapidly (thirty-five days to two months).

5. Operative Technique.—(*a*) *In Esquillectomy.*—(i) *Method of approach.*—The topography of the fracture and the position of any missiles should previously have been determined by X-ray examination, or if possible from a radiograph. There are two available ways of exposing the fracture, according or not as the size and position of the wound provides a way of access.

If the exit wound is large, and not in immediate contact with vessels or nerves, the track of the projectile is followed in the reverse direction, the cutaneous orifice being enlarged if necessary, and the track carefully cleaned; two retractors are placed in position, and any lacerated or dead tissue, all free bony fragments, and all foreign bodies, are removed with forceps. A bistoury is then used to excise any fascia or muscle that it may be necessary to remove in order to prevent closure over the fracture or the retention of any obviously contused tissue. This will sometimes involve enlargement of the cutaneous incision. There should be no hesitation in doing this; the external wound is of little importance, the main point being to discover all the lesions and thoroughly to expose the fracture.

If the cutaneous wounds are small, inconveniently placed, or in contact with nerves or the brachial artery, or in such a position that subsequent care of the wound will be difficult (*e.g.* an axillary wound), the bone is approached by the route of election, that is to say, by an incision over the outer side of the arm between the biceps and the outer head of the triceps.

The bone being exposed, an intact periosteal sheath

will generally be found, particularly in large-splintered fractures; this is incised along an adherent fragment, the incision being begun at the point where the shaft ends, and the rugine is used carefully to free the periosteum on each side of the incision; in this way it is easy in the majority of cases to free a considerable periosteal cavity without actually having removed any adherent piece of bone.

(ii) *Extent of the Esquillectomy.*—Following the usual rules indicated on p. 69, free and loosely adherent splinters are next removed, and when the region of the fracture has been cleared, a further investigation should be made. The object of this, as has been stated before, is to expose any area of medullary contusion, in order to explore the injury completely and to leave behind nothing suspicious.

In large-splintered fractures, this will often lead to the removal of a very adherent postero-external splinter lodged beneath the triceps and corresponding in position to the origins of the inner and outer heads of that muscle, to which it is firmly adherent; very near to this is the radial nerve in the musculo-spiral groove or immediately below it. It is of great importance to detach this very carefully: I make a regular practice of doing so when such a fragment exists, regarding this as the best means of avoiding subsequent involvement of the nerve in the callus, an accident that is very liable to occur, since the nerve generally lies in immediate contact with the fissure, and crosses the fragment like a bridge. In doing this, there is no fear of injuring the nerve if the periosteum is respected; the process is identical with that of liberating the ulnar nerve in resection of the elbow joint: in this way the nerve is pushed beyond the interosseous gap, and will not be involved in any subsequent periosteal proliferation. Further, during this freeing of the nerve, a small missile is sometimes found concealed by one edge of the fragment, which

otherwise would certainly have escaped notice. I am not speaking of the very small free splinters which may also be found, and whose presence explains those little residual abscesses often found near the bone during a later operation for radial paralysis.

Finally, after the operation, the only bone left in the injured region are the two pointed ends of the shaft, in contact at their apices : this I believe to be an excellent result. An examination of the injury to the bone will show that the space left empty by the removal of splinters is enclosed by a hollow cylinder of periosteum, the mould, as it were, of the future callus. In comminuted fractures, there are usually at the periphery short and adherent splinters connected with the shaft above and below ; any of these should be removed with the rugine which are situated near vessels or nerves, particularly the radial nerve. When the esquillectomy is completed, there is an interfragmentary gap of about 1½ inches, in which hang fragments of periosteum : the ends of the shaft are generally oblique and rather ragged. Gentle cleaning of the medullary canal with a small curette should complete the operation. For this purpose it is not generally necessary to proceed further up than the area exposed by the removal of adherent fragments. It is advisable to remove the sharp points of the ends of the shaft with cutting forceps ; in doing this, great care should be taken not to interfere with the periosteum by pushing it aside before applying the bone forceps ; otherwise, what has previously been preserved is lacerated, and there is a risk of spoiling the work of the rugine.

Dressings.—The wounds of entry and exit being cleaned according to the usual rules, and missiles in the neighbourhood of the fracture being removed, the wound is plugged with aseptic gauze. There should be no strip of dressing, and above all, no drainage tube, passing through the wound from one side to the

other: gauze is placed very loosely in the medullary cavity, in the operative incision, and in all other wounds, which should be left widely open. All suturing should be avoided; there is no advantage in partially closing the cutaneous wound at each end, as is so often done: it is never cutaneous healing which retards cure, but deep healing, which suture will not hasten.

For *fixation* purposes, I merely flex the elbow and apply the arm to the chest, which is padded with sterilised wool, and bind it there with soft bandages, an arrangement identical with Velpeau's bandage employed after reduction of a dislocated shoulder. Care should be taken to place a small pad of absorbent wool sprinkled with sterilised talc in the axilla, and to pad the elbow well. This bandage is left in place for several days when all goes well; I have sometimes not touched the dressing before the eighth day.

FIG. 50*a*.—Large-splintered fracture with bony fissures, caused by a shell-fragment.

FIG. 50*b*.—Radiograph showing the result of early sub-periosteal esquillectomy and continuous extension applied to the elbow.

I always change the first dressing under an anæsthetic (ethyl chloride): in this way pain is avoided,

the wound can be examined better, small omissions in the operation can be made good, and the gauze can be placed more exactly where it is required.

If anything necessitates its being repeated later (pain, considerable oozing, or pyrexia), a similar bandage should be re-

FIG. 51.—Total sub-periosteal esquillectomy was performed eighteen hours after the occurrence of this fracture.

FIG. 52.—Result after two months; the wounds have closed, after daily heliotherapy.

applied, and the same temporary fixation arranged: it is advisable not to use a permanent appliance until a regular course of recovery is certain; moreover, well cleaned recent wounds progress well with infrequent dressing. If the case has to be evacuated rapidly, the dressing should be performed on the day previous to that fixed for the evacuation.

For transport a plaster trough covering the shoulder with two small thoracic flaps should be applied. But

this is only a travelling appliance, to be removed on arrival, and is not intended for treatment (fig. 53).

(*b*) *Permanent Reduction and Immobilisation.*—When free esquillectomy has been done, reduction practically follows, and the fracture will unite in the correct position after simple fixation in a plaster splint, provided that the correspondence of the long axes of the fragments has been verified by the X-rays. But if the quantity of bone lost is not great, continuous extension gives a better result since the reduction is more perfect, the fragments are kept well apart and therefore there is no shortening.

FIG. 53.—Plaster apparatus for travelling.

Let us examine the two cases :

(i) *When there is limited loss of bone.* Here there is juxtaposition of the fragments without loss of length in the bone; over-riding is possible and reduction is necessary.

Continuous extension and fixation can be effected by one and the same apparatus, such as Delbet's appliance, or one of its modifications (Leclercq's appliance) or with Alquier's crutch.

In Delbet's appliance the *extension* is exerted above by means of a curved metallic axillary support, padded with cotton wool, and below by a semicircular metal

plate over the upper end of the forearm, the elbow being kept flexed at right angles by a plaster bandage. A hollow rod is hinged to the forearm plate, and within it slides a solid rod connected with the axillary crutch.

Traction is exerte dby a spiral spring which forces the two shafts apart, and these latter are pierced by holes into which a pin can be introduced,

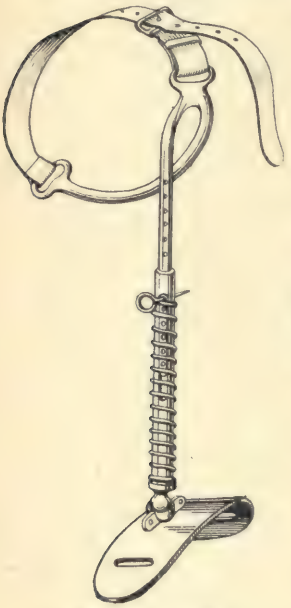


FIG. 54.—Delbet's appliance.

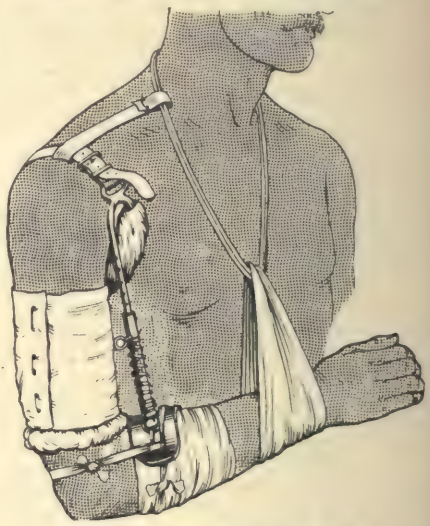


FIG. 55.—Delbet's appliance in place.

and by means of this the spring can be shortened and extension consequently regulated.

This appliance is excellent; sometimes it is a little painful, particularly in fractures high up, where, on account of correction being more difficult, there is a tendency to employ an undue amount of extension, but the reduction of serious displacements can be effected by it. It has the further advantage of leaving the injured region exposed, and of allowing slight

movements of abduction of the arm, and of supination and pronation of the forearm.

When the fracture has been properly set and the correct pressure ascertained, the care of the apparatus is simple; attention should be given to the condition of the skin of the axilla, to which a zinc oxide paste should be applied as a precautionary measure in fat subjects. Particular attention should be devoted to the position of the forearm, which should remain flexed at a right angle; if the angle becomes obtuse, the support slips and extension ceases. The appliance should not be removed until union has occurred.

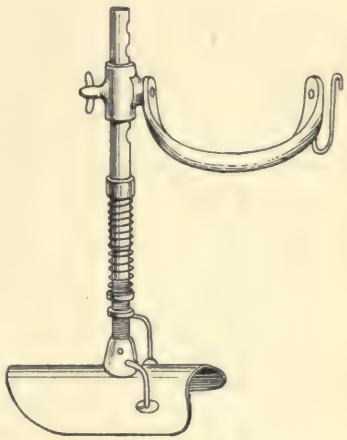


FIG. 56.—Leclerq's appliance.

Leclerq has modified Delbet's apparatus, rendering it interchangeable for the right and left arm. The semicircular axillary support which he employs is wider and longer, and derives support also from the thorax; the lower plate is also wider. The principle is the same; the results are equally good; the disadvantage—that the appliance cannot be improvised—is the same. War surgery requires that it should be possible to construct the necessary appliances on the spot, by simple means and from elementary materials.

Alquier's appliance fulfils these conditions: working upon Delbet's idea and the form of his apparatus, he has given a very practical and interesting solution of the problem.

His appliance can be constructed very easily any-

where and in a few moments, from two iron slats each rather longer than the arm. The upper part of one of these is divided longitudinally into two pieces $5\frac{1}{2}$ in. in length, which are then separated and twisted in such a way as to from a sort of *curved crutch*. The lower part remains as a straight shaft, and is pierced with four holes through which bolts may be passed. A slot is cut out in the upper part of the second slat, while the lower part is bent up in the form of a loop. The crutch is padded with cotton wool surrounded by a flannel bandage and covered with mackintosh. The appliance is then ready. To apply it, a circular plaster bandage is first applied to the forearm from a point slightly above the elbow down to the hand, fixing the elbow at right angles ; it should be moulded round the projections of the elbow. When the plaster is dry, the padded crutch is placed in the axilla, the straight shaft is placed parallel to the internal surface of the arm, and the semicircle of the lower piece is then fitted to the (posterior) under aspect of the elbow, to the outline of which it should correspond exactly ; the straight shaft passes upwards in contact with the arm and with the upper piece. A few turns of a plaster bandage fix the curved piece to the elbow, and when the plaster is set, traction is applied. For this purpose a weight of 4 kilogrammes is suspended from the flexed elbow for half an hour, a short counter-

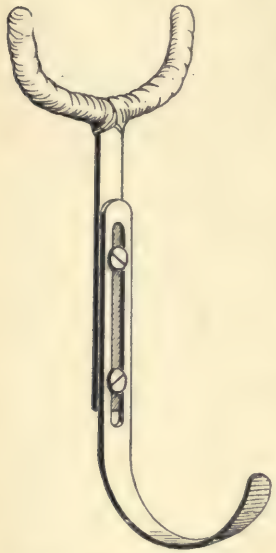
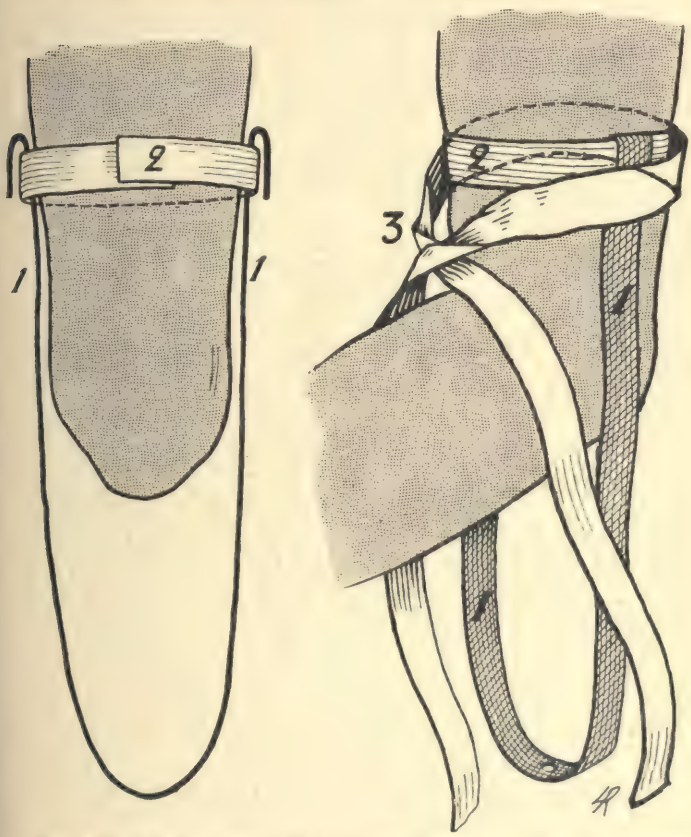


FIG. 57.—Alquier's appliance, with the crutch padded.

extension being applied in the axilla. When muscular contraction is overcome and the fracture reduced, the nuts are screwed up, and nothing further is necessary but to remove the extension and counter-extension.



FIGS. 58 and 59.—Method of arranging the bands for extension.

I regard this appliance as one of the best, if not the best, of all that have been suggested. It is simple, reduces well, does not interfere with dressing, and is

perfect for evacuation : in fact, I consider it the ideal appliance for the front.

At the base, the purposes of treatment can be ful-

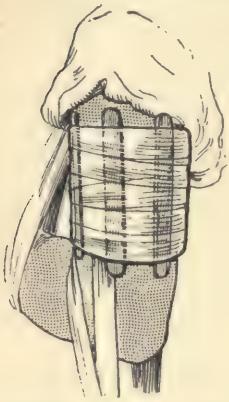


FIG. 60.—Extension effected, with a weight of 1,200 grammes.

filled in an equally perfect way, and still more simply.

In these fractures, particularly after esquillectomy, the displacement is not marked, since the fragments are not under the influence of powerful muscular action; further, when the patient is standing, gravity itself tends to reduce angulation; in fact, *the lower fragment is virtually in continuous extension*; exaggeration of this tendency, effected by suspending a weight above the elbow, is enough to reduce the displace-

ment. On the other hand, permanent continuous extension, if it may so be described, is not necessary for the maintenance of reduction, and intermittent continuous extension (to use paradoxical terms) is sufficient if repeated regularly. This was so in the case of oblique fractures in peace-time ; it is equally true of war fractures. I have regularly employed a very simple continuous extension procedure based on these theories, which is in constant use at Lyons for simple fractures. Like Bérard and Desgouttes, who have also used it, I have obtained excellent results.

With this apparatus, extension is only active when the patient is standing and the elbow is against the side, but experience shows that this is sufficient.

The apparatus is simple. It consists in applying continuous extension by weights above the elbow, and in keeping the fragments immobilised by fixing three or four narrow wooden splints over the dressing by means of a bandage which holds everything together and immobilises perfectly (see fig. 60).

There are several methods of effecting extension :

(α) The weight of the lower fragment may simply be increased by winding round it a sheet of lead (800 to 1,000 grammes), in the form of a figure-of-eight, the upper loop of which surrounds the humerus and the lower the elbow.

(β) A collar in the shape of a figure-of-eight may be applied, identical with Hennequin's used for fractures of the thigh ; this is made of linen or similar material, and a suitable weight is hung from the lower loop.

(γ) Lastly, regular traction may be effected by means of adhesive strapping : this is the method which I usually employ ; it is more exact since the pull can be exerted in a slightly anterior or posterior direction when X-ray examination shows this to be necessary.

The patient being seated, and the elbow flexed at a

slightly acute angle, a loop of strapping is first applied in the shape of a U, the vertical limbs passing vertically upwards on each side of the elbow and arm as far as possible, exactly parallel to the long axis of the shaft. To ensure more perfect adhesion, the upper bands may be cut into short strips and splayed out on the arm. This done, the vertical loop is fixed by means of a circular piece of strapping over which the upper limbs of the U are reflected. A third and very long piece describes a figure-of-eight, the upper loop passing round the humerus, the lower surrounding the elbow. A circular band of strapping round the arm fixes the upper loop, while the lower is united with the loop of the vertical U. It is from this that the weight is suspended. The final appearance of the appliance is shown in fig. 60.

A pad of wool should be placed in the axilla to force the upper fragment slightly outwards. The forearm is supported by a sling. At night the weight is supported or removed, to be replaced in the morning.

When the dressing needs replacement, it is sufficient to remove the immobilising splints without interfering with the extension ; carried out in this way, dressing is painless, if the patient is seated—that is, if extension is active.

The initial weight used should be 500 grammes, gradually increased to 1,200 grammes.

The simplicity of this appliance should not deter one from using it: the radiographs reproduced here (figs. 61 and 62) show a perfect reduction effected by it. The only disadvantage is that it cannot be used for cases that are obliged to remain in bed ; in such cases it would be satisfactory merely to exert a horizontal pull, using the bar of a chair or any other similar arrangement as a pulley, but a suspension appliance such as will be described later is preferable.

When the formation of callus begins, after thirty to forty days, the wounds are usually reduced in size

and require dressing only at long intervals; at this stage I replace the extension by a plaster trough, including a cap moulded on the shoulder (fig. 51), but I have occasionally retained the extension appliance until complete cure was effected.

(ii) *When there is an interfragmentary loss of bone caused by the missile and cleared out by esquillectomy,*

FIG. 61.—Fracture of the humerus caused by a bullet, with punctiform cutaneous wounds; before continuous extension was applied.

FIG. 62.—Result of continuous extension by simple application of a weight to the elbow (figure-of-eight arrangement of strapping). This radiograph was taken eight days after that in fig. 61.

continuous extension is unnecessary; reduction consists in immobilising in good position, for which plaster is sufficient: simple traction exerted on the plaster while it is drying brings the fragments into line, without the possibility of anything becoming interposed between them.

If the wound is not too large and runs an aseptic

course, a fenestrated plaster bandage may be applied, similar to that described on p. 118. As a rule, however, the wound in the soft parts is extensive and requires for its care comparative freedom of the arm, while it is better also that regular exposure to the air and sun should be possible.

After many experiments with interrupted plasters, I have abandoned these in favour of an appliance that has given me consistently good results for the last six months.*

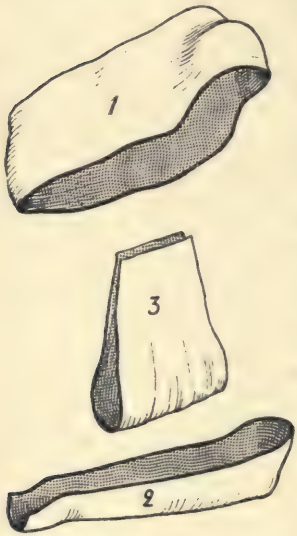


FIG. 63.

Two plaster bandages and three tarlatan splints each consisting of twelve thicknesses are prepared; one of these is passed round the chest and closely applied to the prominence of the shoulder (an essential point); another is used as a trough for the forearm, passing behind the elbow and a variable distance up the humerus; the third is used as a sling supporting the forearm splint (fig. 63).

Sometimes before and during the fitting of the appliance it will be found well to apply continuous extension to the elbow by means of a weight and a figure-of-eight-shaped collar, described on p. 145.

A large quantity of rather thin plaster paste is prepared, and the first step is to apply the large support

* Since this was written (June 1916) I have more and more generally used a simple external trough for the arm, dressing the wound at long intervals. The results have been excellent. On the other hand, I have seen in use the appliance of Alquier described above, and I think it is preferable to the plaster described here.

obliquely across the chest, moulding it well to the contours by well-placed depressions, and passing it over the shoulder. The slight final adjustments required for exact adaptation should not be hurried (hence the necessity for a thin paste). The trough for the forearm is then applied, the elbow being flexed and the hand pronated, with the thumb directed upwards. The edge of the splint should go as far as possible up the posterior aspect of the elbow, and the latter should be firmly surrounded by it. The sling is then adjusted in a good position and fixed by a safety pin.

FIG. 64.

When this has been done and the position of the arm has been verified and the fragments of the humerus have been found to be well in line, the three parts of the appliance are united with plaster bandages. When all is complete, only a half to two-thirds of the arm is exposed, and the two articular ends of the humerus are absolutely fixed (fig. 64).

This appliance is extremely convenient, and if well constructed, gives perfect results. After early subperiosteal esquillectomy, union generally occurs at the end of six weeks, and the appliance can be kept in place for the whole of this time.

For patients obliged to remain in bed, a suspension

appliance is the best. Continuous horizontal extension is first applied in line with the long axis of the arm by a weight of 1,200 or 1,500 grammes; the arm is then suspended by two triangular bandages wide

FIG. 65.*

enough to support the fragments well; these two bandage-supports are fixed to a small piece of wood

* For the sake of clearness, the bandage slings have been represented as rather narrow.

suspended from a pulley by a cord carrying the weight necessary to counterbalance the arm (usually 2 kilograms); the forearm, bandaged firmly over cotton wool, is suspended from a second pulley (see fig. 65).

6. TREATMENT OF CASES SEEN AT A LATE STAGE OR ALREADY UNDER TREATMENT.—Five possibilities should be considered:

(*a*) *A case progresses well after no operation or after an inadequate one.*—The wound, for instance, dates from five or six days previously, and the dangerous period has passed; there is no suppuration and no swelling. Such a case is very unusual. If no foreign body can be detected by X-rays within or near the bone, it is sufficient to employ continuous extension by the methods explained above (traction applied above the elbow through adhesive strapping).

FIG. 66.—Large-splintered fracture of the humerus. Total sub-periosteal esquillectomy was performed during the second day.

FIG. 67.—Result after two months of continuous extension by weights applied to the elbow; there was no pyrexia.

The course will be that of a bullet-fracture with punctiform skin orifices, *i.e.* that of a simple fracture.

If a foreign body is present, the steps to be taken depend upon its situation. If it is intra-osseous, exploratory sub-periosteal esquillectomy should be undertaken in order to remove it: delayed sepsis is, in fact, very probable, and its development should be prevented; removal, too, is easy in this early stage, whereas it is very difficult when it necessitates penetrating to the centre of a more or less recent callus.

If the missile is outside, but near the bone, the surgeon may either wait for the development of a small abscess which commonly forms, before removing it, or, after localisation, may remove it at once; this latter course, in my opinion, is decidedly preferable.

(*b*) *A fracture, after an inadequate operation, becomes subsequently profoundly septic.*—After X-ray examination, and localisation of the foreign body, if one is present, sub-periosteal esquillectomy and drainage should be carried out as early as possible; this is conducted exactly in the same way as the operation in the early stage. Eight to ten days after the operation, the condition of the fracture should be determined by a radiograph. If the wound is suppurating, or any débris remains overlooked, it should be removed, and subsequent clinical asepsis will usually be assured in eight to fifteen days. The fracture will unite normally without the tracking of pus to points remote from the wound, and without muscular sclerosis. Sometimes, however, after three or four weeks, superficial healing will apparently be arrested or a little pus will appear; this leads to the conclusion that there is slight osteitis of one end of the shaft, the marrow of which had been infected. After confirmation by X-rays, it will usually be easy with forceps to find a small and still adherent inflamed sequestrum, the removal of which will immediately

abolish these complications (see figs 28, 29, and 30, pp. 62, 63).

Union usually occupies a month and a half, and complete cutaneous healing two months.

(*c*) *A case is seen at a late stage* (*after a month*) *suppurating more or less freely.*—The advisability of an operation on the bone is *very doubtful*; osteomyelitis has seriously affected the region of the fracture, which should be interfered with as little as possible; abscesses should be incised, and the wound drained, but only completely free splinters should be removed.

Esquillectomy on the lines advocated above would very possibly give rise to acute septic phenomena, and would injure the region without completely clearing it. It is better to refrain, immobilise, drain, and wait, meanwhile expecting a sinus to form.

(*d*) *A case is seen with a sinus.*—Instead of blind exploration with the próbe, an X-ray examination from two aspects should be made to determine the cause of the sinus; sometimes it will be a foreign body which must be extracted, more often it is a patch of superficial osteitis with a peripheral cavity partially enclosing a small sequestrum. A central cavity of variable size is almost always found; the sides of this must be widely cut away, the edges bevelled, and the interior displayed as completely as possible, after removal of sequestra, if any are present. With this in view, the bone should preferably be approached from its outer aspect, not forgetting the presence of the radial nerve in the lower third of the arm.

(*e*) *A case is seen with pseudarthrosis.*—There should be no confusion between pseudarthroses and extensive losses of bone deliberately produced in a case of extensive crushing of the bone, when, the nerves and vessels being intact, it has been desired to avoid amputation.

The term pseudarthrosis is only applied if union fails to occur between fragments reasonably close

together. When a great length of bone has been lost, union is impossible; conditions are unfavourable for grafting, and it is better, at least temporarily, to fit a prosthetic appliance.

Pseudarthroses, on the other hand, should be treated by immediate operation; it is in no way necessary to wait for complete superficial healing of the wound before uniting the bone. It has seemed to me that the operation is more successful when the bones are infected and osteitic than when they are atrophied, worn away, and devitalised. I believe it is well, when possible, to send the patient for a preliminary stay at the seaside, or to treat him by sunlight, in order to strengthen the musculature, restore tone to the skeleton, and disinfect the tissues. The time employed in this physio-therapeutic cure is not lost, and it is largely to this that I attribute my habitual success in treating pseudarthroses of the humerus.

I believe that, from the operative point of view, osteosynthesis is preferable to grafting. Gunshot wounds are very bad media for a bone-graft; failures have been and will be numerous: on the contrary, osteosynthesis by Lambotte's plate or by wiring gives perfect results in the humerus.

When the operation has been decided on, the region of the fracture is very widely exposed by a long incision external to the vessels and nerves. The ends of the bone are freed with the rugine for a considerable distance in each direction, and every effort must be made to preserve as extensive a sheath of periosteum as possible; these extremities are resected to a sufficient extent to leave them symmetrical and consisting of healthy bone; the ideal is to find a normal medullary canal on section. All the interfragmentary fibrous tissue is excised, after which the extremities are fastened in position by one or two Lambotte plates and long screws.

The wound is left open and simply plugged. It

is undoubtedly possible in certain cases to sew up the incision again, and effect a cure by first intention. But in addition to these fortunate cases, there are many serious failures—suppuration, separation of the bones, recurrence of osteitis and a return to the condition of pseudarthrosis. If the wound is left open, no risks are run; progress is aseptic, and dressing is required only at infrequent intervals. I apply a plaster trough and leave the dressing in place as long as possible; at the end of seven or eight weeks the plates may easily be removed when union has begun.

IV. Supra-condylar Fracture of the Elbow

1. Anatomical Features.—These common fractures occur immediately above the lower epiphysis of the humerus. They are usually comminuted; frequently one of the fragments of the shaft tapers gradually to a pronounced point, which is directed forwards in the case of the lower fragment, and backwards if it forms part of the upper.

There are often fissures running towards the joint; these sometimes end close to it without splitting the epiphysis; more frequently they reach the cartilage. If the injury is very violent, the fracture distinctly involves the joint, the humeral condyles are broken and the cartilage is shattered; there is, in fact, a condition constituting a definitely articular fracture.

There are sometimes associated nervous lesions, usually of the ulnar.

2. Physiological Features.—There is, as a rule, no displacement; the lower fragment inclines slightly forwards, and sometimes this is all; it is, however, serious, since, owing to this anterior inclination, union is difficult and the fracture is liable to pseudarthrosis.

There is often also separation of the lower fragment due to the weight of the limb, which carries the forearm and elbow either outwards or inwards.

3. Course.—The characteristic feature of this fracture is the presence of fissures running down towards the joint. They are unimportant if the fracture remains aseptic, since their repair and disappearance then follow very rapidly; if, however, there is any infection, it will invariably extend to the joint, and osteomyelitis in the region of the fracture is soon complicated by arthritis, at first serous and later suppurative.

Fig. 68.—Radiograph of a case which had suppurated for eight months without operation; numerous sequestra were eliminated spontaneously. The elbow was ankylosed in extension.

If the fracture has not been cleaned, and the infection is not virulent, a paradoxical development may be observed: the arthritis ends in ankylosis, and the fracture, failing to unite, ends in pseudarthrosis. I have examined three cases in which this curious result has been observed; it was favourable in one case, poor in another, and deplorable in the third (fig. 68).

But more often infection of the joint develops in a serious way, and necessitates secondary resection, if not amputation. Resection may give a good result, if it is kept strictly sub-periosteal and if the injuries do not extend too far up the limb; sometimes, however, some inches of the shaft are destroyed, and resection, though necessary, leaves a flail-elbow.

4. Indications for early Treatment and details of Technique.—The only means of avoiding the serious early and troublesome later developments enumerated above (severe articular infection, supra-

epiphyseal pseudarthrosis) is to perform early complete sub-periosteal esquillectomy which will permit exploration of the fracture and an aseptic subsequent course.

All other operations are uncertain in their results and leave the joint in danger.

Method of approach.—The best method of exposing the region widely is to make a free incision posteriorly

FIG. 69.—Supra-epiphyseal fracture of the elbow; joint intact.

FIG. 70.—Radiograph after early sub-periosteal esquillectomy; asepsis resulted. Case evacuated in satisfactory condition in fifteen days (June 1915).

in the median line through the triceps. Two retractors enable the surgeon to inspect the fracture and act as may be necessary: all fragments of bone are removed and every effort is made to preserve as much periosteum as possible. When the region has been cleaned, it will sometimes be well to trim the two extremities of the shaft with a saw, in order to produce even surfaces in the region of which aseptic development will be more easy. If there is a splinter-

like point, it should not be sawn away, but the rest of the circumference should be an even section.

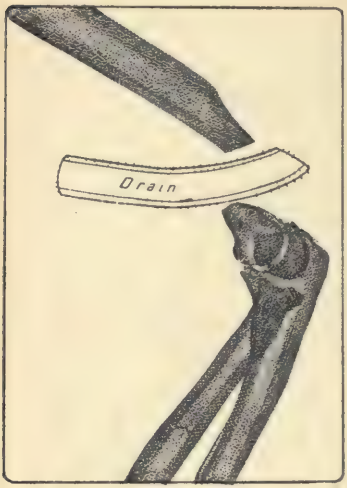


FIG. 71.—Supra-articular fracture of the humerus by a shell-fragment, September 29th, 1915. Total sub-periosteal esquillectomy performed on the following day with trimming of the extremities with a saw. The radiograph reproduced above was taken ten days afterwards. On December 1st the plaster was removed and the wound found to be completely healed without sinuses, and a radiograph showed an anterior periosteal callus uniting the fragments perfectly. Flexion of the elbow was limited by the projection of this block of ossification, but flexion to beyond a right angle was possible, and extension to about 160°.

FIG. 72.—Radiograph after six months: flexion possible to considerably more than a right angle; full extension; muscular action perfect; slight torsion.

If deep fissures are found, and it is probable that they extend to the joint, they may be disregarded if the operation is being performed in an early stage. If infection is already evident, its extension to the joint may still be avoided, but is very much to be feared. It is not necessary, however, unless the injury to bone is very

extensive, to perform resection of the joint at once, since a favourable course is still possible. If the opposite is the case, there should be no hesitation in performing this operation, but the periosteum, capsule, and muscular insertions must be preserved carefully. By an "exaggerated" sub-periosteal operation I was able, in a case of this kind, to obtain regeneration of the shaft and epiphysis to the extent of about 4½ in., with very satisfactory functional play of the elbow.

The operation of esquillectomy and trimming with the saw being completed, fixation should be effected by a posterior plaster trough with the elbow fully flexed: the best reduction can be obtained in this position. I have never employed any other plaster but the posterior form, and I find it decidedly preferable to interrupted appliances for strict immobilisation of a fracture the course of which is, as a rule, very simple after careful esquillectomy. The plaster is removed for each dressing, which may be delayed for an average of at least seven or eight days.

Union occurs with considerable rapidity, although the periosteum of this region is not very fertile; it has generally been effected in my own cases within a month or two.

5. TREATMENT OF CASES SEEN AT A LATER STAGE, OR ALREADY UNDER TREATMENT.—(*a*) *A case is seen progressing well.*—Rigorous fixation in the flexed position is alone required; the meaning of the words "progressing well" should, however, be well understood; this means to say that the wound is absolutely aseptic, without the slightest discharge. If there is any suppuration, secondary arthritis (of which no signs sometimes appear until the tenth or twelfth day) is always to be feared, in spite of favourable appearances, and immediate total esquillectomy should be performed.

(*b*) *A case is seen with a septic wound.*—Immediate total sub-periosteal esquillectomy is necessary; there

is no other means of cleaning the region of the fracture and preventing involvement of the joint. If arthritis is present, and there are markedly infected fissures, strictly sub-periosteal resection of the whole humeral epiphysis should be performed. I have carried out this late secondary resection on three occasions in cases evacuated from the front in a seriously septic condition. Very complete periosteal regeneration was obtained (see figs. 42, 43, 44, 45 of Vol. I) and the results have been satisfactory : the arm was firm, and a good degree of the normal range of voluntary movement was regained. As a precautionary measure, I applied a small copper splint with rigid springs, to give more fixity to the joint.

(*c*) *A case is seen with fistulous osteitis.*—Unless the case is one of superficial osteitis, easily curable by a small operation, resection of the elbow is frequently necessary.

(*d*) *A case is seen with pseudarthrosis.*—If there is no infection, an incision may be made along the median line through the triceps, and the bones united by a Lambotte plate or metal wire, after excision of the interfragmentary scar-tissue. I have never had occasion to do this.

CHAPTER IV

FRACTURES OF THE FOREARM

THE treatment of fractures of the forearm cannot give good results unless we take into account certain new physiological factors which regulate the mechanical conditions under which the forearm and hand perform their functions, since these factors ought to direct the treatment before and during the formation of the callus.

The treatment of fractures undoubtedly demands a clear comprehension of local physiological conditions in any region in order to attain its object, which is the most perfect functional recovery possible for the bone lever concerned; but, if necessary, an enlightened empiricism can take the place of physiological theory.

In the forearm this is not so; the forearm has a special function, the integrity of which is necessary for perfect movement of the hand. The surgeon who does not understand its physiology exactly, that is, who does not understand the precise mechanism of pronation and supination, will often be responsible for functional disasters which a better-informed man will easily avoid.

I consider this is so important that I shall depart from the usual plan of this little volume and first explain these fundamental physiological views: they are still little known, having only recently been de-

finitely stated.* All this knowledge is owing to Destot, who has constructed an original theory of the functions of supination and pronation based upon radiographic analysis; the problem is thus definitely solved, notably from the surgical point of view.

The following points must be clearly understood before the surgeon can treat a fracture of the forearm suitably:

(1) Pronation and supination are exclusively effected by the radius, which revolves round the ulna, carrying the hand with it; the ulna only moves slightly in an antero-posterior direction.

(2) The axis of rotation of the forearm is oblique; it may be represented by a line connecting the head of the radius with the lower extremity of the ulna.

(3) The head of the radius revolves in a socket, while the distal end of the bone undergoes circumferential movement round the head of the ulna: the transformation of the movement at the proximal end (rotation on its own axis) to that at the distal end (circumferential rotation—*i.e.* round an external axis) is caused by the outward curve of the radius, and by the existence of a cervico-diaphysial angle. If the shaft were straight, the movement would remain axial and consist in simple rotation on that axis.

(4) During this movement, the width of the interosseous space remains fixed, whatever be the position of the two bones. In radiographs the interosseous space appears wider in pronation than in supination, but this is an error of projection: the width of the space does not vary if the plates exposed are placed parallel to the plane of the dorsal aspect of the wrist.

(5) The lower part of the ulna is a sort of pivot round which the distal extremity of the radius moves:

* It has been my first object in this to be as clear as possible, referring the reader for greater accuracy and fulness to the recent treatise on fractures in which Tanton, dealing with peace-time fractures, gives a complete exposition of this difficult question, and of the work of Destot.

the latter is so constituted that it is always in the same degree of pronation or supination as the upper extremity.

(6) The upper and lower radio-ulnar joints are, so to speak, lateral hinges, which only maintain their connection if the relative length of the two bones is maintained constant: these joints are connected for a unique purpose, and equality in length of the bones is a necessary factor for their normal functioning.

It follows from these laws of Destot that four fundamental conditions control the physiology of the forearm:

Preservation of the outward curve of the radius, permitting the movement of circumduction in the lower extremity;

Preservation of the relation between corresponding points in the head and the distal extremity of the radius;

Equality in length of the bones;

Preservation of the axis of rotation of the forearm.

It will be understood from this to what objects the treatment of fractures of the forearm should be directed.

Three varieties of fractures of the forearm must be studied:

Fracture of both bones;

Fracture of the radius only;

Fracture of the ulna only.

I. FRACTURES OF BOTH BONES OF THE FOREARM

From the point of view of treatment three different types exist:

Fractures just below the elbow joint;

Fractures of the shafts proper;

Fractures just above the wrist.

A. Fractures just below the Elbow Joint.

1. Anatomical Features.—These fractures are

usually caused by great violence and are comminuted; the radius is broken in the region of the neck, and the ulna below the sigmoid cavity, but there is frequently an internal splinterlike projection, and the bicipital tuberosity remains as a part of the upper fragment. In the more simple type there are no radiating fissures, but the injury is frequently more complex; in the radius at least, the cartilage is split, and the fracture is therefore intra-articular. Fissures involving the joint are less usually seen in the ulna, the coronoid process and olecranon being very resistant, but long fissures frequently travel down the shaft of the ulna.

The posterior branch of the radial nerve may be injured close to the neck of the radius.

2. Physiological Features.—There is little displacement of the fragments of the ulna; those of the radius, however, exhibit it constantly: the head and neck are displaced by the biceps, which remains, at least in part, inserted into the upper fragment in which it produces a combined movement of flexion and supination: hence, the head of the radius swings forward and turns on its axis, while the shaft, under the action of the pronators, assumes a position of full pronation.

3. Course.—As a result of muscular action, even in the most favourable cases when infection does not necessitate early intervention, union of the radius is difficult, and even if it occurs, the two fragments concerned are generally displaced (*i.e.* rotated) in opposite directions.

In fact, there is at least a tendency to radial pseudarthrosis, and a risk of losing the power of supination and pronation.

On the other hand, particularly in mild cases, when the bicipital tuberosity has been smashed up and the biceps consequently put out of action, a radio-ulnar synostosis may occur, which prevents the movements of pronation and supination. These results, however,

are rare, for the sufficient reason that this highly splintered region is usually seriously infected. The infection extends to the joint along the fissures, or simply as a result of contiguity, and if early acute septic phenomena have not occurred, marked suppurative arthritis soon develops; the upper fragment of the radius undergoes rapid necrosis, and formidable complications ensue. Unless resection is performed, arthritis often ultimately necessitates amputation.

FIG. 73.—Radiograph showing displacement of fragments in a sub-epiphyseal fracture of the radius and ulna by a shell-fragment. Operation twelve hours later, and cure effected, but with radio-ulnar synostosis. Flexion and extension of the forearm are normal. Pronation and supination are not possible. The result is remarkable.

Further, pus rapidly forms in the region of the ulnar fracture and abscesses spread among the flexors and damage them seriously (see p. 172). The flexors undergo necrosis, and there is marked interference with finger movements. I have seen a case at a medical board with ankylosis of the wrist secondary to a sub-articular fracture of the forearm; infection had passed along the flexors and produced radio-carpal arthritis.

In the rare cases which run a favourable course, ankylosis generally occurs, with a persistent osteitis of the radius; the power of pronation and supination is permanently lost.

Sometimes sub-articular radial pseudarthrosis may occur; contrary, however, to what might naturally be supposed, there is no functional improvement.

In brief, suppurative arthritis, ankylosis, pseud-arthrosis, radio-ulnar synostosis, and contraction of the flexors, are the dangers in sub-epiphyseal fractures of the bones of the forearm.

4. INDICATIONS FOR EARLY TREATMENT.—The only means of avoiding arthritis of the elbow joint consists in completely cleaning the fracture area as early as possible. For this purpose, whenever circumstances permit, there should be a previous examination by X-rays or by a radiograph.

If the fracture is limited and no fissures are visible, anatomical conservation may be attempted, that is to say, only sub-periosteal esquillectomy is performed. The osteogenetic power of periosteum near the epiphysis is, however, not very great ; moreover, the neck of the radius is displaced, with the fractured surface pointing upwards, and under these conditions a good anatomical result is difficult to obtain. When union occurs, the cervico-diaphysial curvature of the radius, which has been discussed in connection with the physiology of the forearm, is generally abolished, and the power of pronation and supination is lost.

Owing to these bad local conditions, when fissures extend to the epiphysis, when the damage is considerable, and particularly when operation is not distinctly early, I believe that sub-periostial resection of the elbow is preferable. More extensive lesions are always found in the joint than were expected ; moreover, resection has the advantage of ensuring complete prevention of serious infective developments, and of enabling repair to take place under aseptic conditions. I have obtained a very good functional result in two cases of this kind.

If, on the other hand, the fracture involves the shaft more than the immediate vicinity of the epiphysis, I believe simple esquillectomy to be preferable.

It is on account of these different possibilities that a preliminary radiograph is necessary.

Technique.—In all cases, exploration of the region should be begun by an incision of sufficient length to expose it thoroughly. A posterior median incision, slightly external to the ulnar crest, is preferable: by this means the condition of the radius and ulna may be easily investigated. Clearance with the rugine may be immediately begun on the ulna. Injury to the flexors should be avoided as far as possible. If resection appears necessary, it should be total, that is, the articular ends of all three bones should be resected: the humerus is sawn through below the epitrochlear-epicondylar line, only the cartilaginous surface being removed. I explained in Vol. I, p. 86, why these rules should be followed: the mutual adaptation of the bones is better, and the functional results are more perfect. I shall not discuss this further.

5. Treatment of cases first seen at a late stage, or already under Treatment.—(*a*) *A case unoperated upon is doing well.*—If no foreign body is present, intervention is not required, but merely rigorous immobilisation, the elbow being flexed to an acute angle in order to approximate the two fragments of the radius. I have seen remarkably good functional results follow this simple treatment.

If a foreign body is present, its immediate removal is preferable to delay.

(*b*) *A case is seen with a septic wound.*—If the infection is confined to the shaft, sub-periosteal esquillectomy through a posterior incision is sufficient.

If, on the contrary, the fracture implicates the epiphyseal ends at all, or if there is the slightest sign of involvement of the joint, sub-periosteal resection, extensive as far as the bones of the forearm are concerned, but limited in the case of the humerus, should be performed at once.

(*c*) *A case is seen with a sinus.*—After X-ray examination, and according to the nature of the lesion, the following steps should be taken:

Removal of a sequestrum or splinter, if the bony lesion is limited.

Resection, if injury to the shaft is not extensive, and if the joint is clinically involved.

(*d*) *A case is seen with a pseudarthrosis of the radius.*—It will be sufficient, as a rule, to remove the upper fragment, that is, the head of the radius from behind, to obtain great functional improvement, provided that the fragment does not include much of the shaft. It is necessary for pronation and supination that the radius should be fixed at its upper extremity; the annular ligament must, in fact, support all or part of the neck of the radius.

B. Fractures of the Shafts.

1. Anatomical Features.—The fragments are usually small, and not markedly displaced, except in bullet wounds showing explosive effects; the latter are very frequent, and, owing to their variety, are impossible to describe. It is exceptional to see the large-fragment type, but the cuneiform fragment is often seen in both bones (fig. 75), or the butterfly-wing fracture.

The injuries are situated at the same level in the two bones or at different levels, according to the angle of incidence of the projectile.

An important fact is that the extent of the fracture is not usually the same in the two bones.

There is, as a rule, little longitudinal displacement; on the other hand, the force of impact almost always causes antero-posterior displacement with postero-lateral angulation.

According to its situation, the fracture is either buried beneath the flexor muscles, or, on the other hand, superficially situated in the tendinous part of the forearm. This distinction is important.

Associated injury to nerves is frequent.

2. Physiological Features.—These are of the

first importance. In the first place, the fracture destroys the equilibrium of the muscular forces of pronation and supination: nothing can prevent the upper fragment from being completely and permanently supinated by the contraction of the biceps, the supinator *par excellence*. On the other hand, the lower fragment is given over to the unrestricted

FIG. 74.—Comminuted fracture.

FIG. 75.—Cuneiform fracture.

pronating forces exerted by the pronator teres and particularly the pronator quadratus.

The two fragments consequently rotate on their long axes in opposite directions; in the words of Destot, "*ils se décalent*" (disconnection, or counter-rotation, occurs), and if this is not corrected, if the two fragments unite in the position imposed by the antagonistic muscular forces acting on them, the bones unite, with the muscles completely relaxed: pronation and supination become permanently impossible.

Moreover, owing to the momentum of the missile, the fragments of the bones are frequently displaced

laterally. If the displacement occurs inwards, angulation is produced with the apex to the inner side of the forearm. The effect of this is to abolish the external radial curvature, an essential factor, as we have seen, in the production of the rotatory movement which is the basis of transition from pronation to supination.

This, therefore, is a further danger which threatens the essential function of the forearm.

The other lateral displacements are less serious, but always diminish the possible range of pronation and supination.

There are further physiological aspects to be considered in fractures of the forearm, which will be studied in connection with the course of the cases.

3. Course.—Apart from the very serious fractures from bullets causing explosive effects in the soft parts, these fractures are less frequently fatal than fractures of the shafts of other bones. Apart from cases of gas gangrene, which are always possible if early disinfection of the fracture has not been carried out, death does not result from fractures of the radius and ulna : the bones are too superficially placed and too accessible to permit the development of the most serious phenomena of sepsis. But although death may not result from a fracture of the forearm, amputation of the arm may be necessitated by a fracture of this kind, and, above all, loss of use of the hand and fingers may very easily result from it.

In fact, though less serious than elsewhere, since the formation of a closed cavity is less likely to occur in this region, the development of septic conditions is equally constant.

Suppuration causes local changes, the functional results of which are deplorable. There are two types, according as the fracture is situated in the muscular or the tendinous part of the forearm.

(*a*) *In Fractures in the muscular part of the Forearm.*—Tracks of pus separate the muscles, insinuating

themselves between them. If this condition is treated by repeated and prolonged drainage, damage to and loss of substance of the flexor muscles result from contact with pus and drainage tubes, and even from the operations required; these lesions ultimately result in sclerosed muscles and contracting scars.

During the active stage of infection this manifests itself by flexion of the two last phalanges upon the palm of the hand. This condition is very painful, and the slightest movement of the fingers causes considerable suffering; moreover, unless it is corrected at an early stage, muscular scarring will render it permanent and the fingers will remain flexed. When this contracture is studied, it will be seen that there is no possibility of straightening the fingers while the wrist is extended. If, on the other hand, flexion of the wrist is carried out, extension of the fingers is possible. There is therefore a syndrome of cicatricial shortening of the flexors identical with that caused by ischæmic paralysis, and this, being caused by a loss of substance and cicatrisation, is a permanent lesion. It can only be remedied by shortening the bones, which are already diminished in length by the fracture; this operation, in a forearm infected for a long period, is done under very unfavourable conditions, and its functional result remains doubtful.

This muscular complication in high fractures of the shafts is therefore much to be feared, which amounts to saying that the infection causing it should be anticipated.

(*b*) *In Fractures in the tendinous part of the Forearm.*—The infected fractured region is in immediate contact with the tendons and their sheaths. Further, it frequently happens that certain tendons have been injured directly by the projectile; they are severed or lacerated, but repair is possible if the injury remains aseptic; they necrose and are eliminated if it suppurates. After a long period of suppuration, their

ends adhere to the skin, become involved in a block of scar tissue in such a way that when anatomical cure is obtained, functional recovery has become impossible, and the use of the limb is permanently impaired.

Wherever, in fact, the fracture may be situated, the consequences of infection are deplorable from the functional point of view.

This, however, is not all that may supervene in fractures as a result of infection; sepsis also introduces a danger of pseudarthrosis, and in the following way. The gap between the fragments is usually wider in one bone than in the other; as fragments gradually undergo necrosis and are eliminated, there is a loss of bone substance in each case, but this gap is wider in one than in the other; hence a tendency to pseudarthrosis of one bone.

Add to this the serious disturbance caused by torsion in opposite directions, and the gravity of fractures of the forearm from the functional point of view will be understood.

Everything possible should therefore be done to prevent infection, to avoid pseudarthrosis, and to reduce the fracture suitably.

4. Indications for early Treatment.—The first necessity in this case as in all others is completely to prevent the development of septic conditions by thorough exposure of the affected region; permanent asepsis assured in this way will facilitate reduction and its maintenance.

It is further necessary to reduce the gaps between the fragments to the same dimensions in order to facilitate union, to correct torsion, to reduce lateral displacements, to keep lesions of the flexors under observation, and to repair injuries to tendons.

Complete recovery of the functions of the hand, to which treatment is mainly directed, is therefore a very difficult matter.

Emphasis is again laid on the fact that asepsis of the fracture is an essential condition.

For this reason complete sub-periosteal esquillectomy should be performed after an X-ray examination as early as possible.

I am aware that some surgeons regard it as useless because grave sepsis is uncommon, but I consider this argument worthless. The object of intervention is to *ensure in all cases as complete a preservation as possible of the movements of the hand, and of pronation and supination.* This object is worthy of considerable effort, and systematic intervention is the only means of attaining it. There is no other way of avoiding that fistulous callus-formation, which is sometimes obtained with difficulty after several months, leaving the forearm thin, scarred, and deformed, the hand flat, its muscles degenerated, and the fingers shrunken, weak, and clumsy.

5. TECHNIQUE.—Esquillectomy is carried out, when choice is possible, by means of a median posterior incision if the fracture is situated high up; this incision should pass slightly outwards from the ulnar crest, and will often be sufficient. This will avoid the necessity of making a second incision over the radius, which would risk severance of the motor branches to the extensors.

In the middle of the forearm it is preferable to make two lateral incisions, each over the projecting part of the bone to be exposed.

As the fragments are usually small and not much displaced, some determination is necessary to perform adequate esquillectomy, that is to say, to remove each splinter by careful use of the rugine. The necessity of avoiding injury to the periosteum need scarcely be emphasised. Care must be taken to free the muscles from minute splinters which may be adherent to them. This practice will obviate a great deal of abscess formation in the later stages.

After clearance of both fractures, the width of the interfragmentary gaps should be compared, and these should be reduced to the same dimensions: the best instrument for this purpose is a Gigli saw. Precautions, however, should be taken to protect the periosteum,

Fig 76.

Fig. 77.

Fig. 78.

Fig. 76.—Radiograph after complete esquillectomy for fracture of both bones of the forearm by a rifle bullet with great explosive effects. The operation, performed on the fourth day, obviated the necessity of amputation in a case seriously affected by infection, due to multiple wounds, including a fracture of the tarsus.

Fig. 77.—Two months later. Approximation of the fragments. The two extremities of the radius are in process of periosteal fusion; the fragments of the ulna are less widely separated than before, and the neighbouring periosteum is very active.

Fig. 78.—Two months later. Union is complete in the radius without a sinus. The ulna has not reunited, but this pseudarthrosis gives little trouble. The fingers are stiff, but no tendons have been destroyed. Resection of the radius, by equalising the interfragmentary gaps, would probably have effected union of both bones.

since it may otherwise be lacerated by the saw, and periosteal regeneration thereby jeopardised. After the operation, a dressing of aseptic gauze is applied to each wound. The forearm is immobilised in a position

of supination and semi-flexion. The best means of effecting this is a posterior plaster trough, with an aperture for the thumb, and enclosing the palm of the hand (fig. 87, p. 195).

If esquillectomy has been performed correctly, no difficulty will be experienced in reducing the fracture and maintaining reduction; for this reason, I consider continuous extension unnecessary.

After some days, when the wounds are healing normally, an

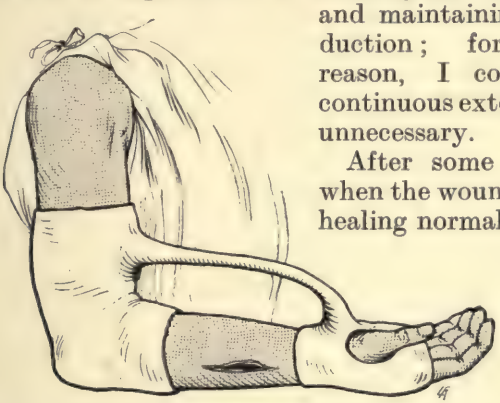


FIG. 79.—Interrupted plaster splint for fracture of both bones during consolidation.

interrupted plaster splint may be substituted to facilitate dressing, but it is better not to apply this early, unless the condition of the wound requires it.

This plaster includes :

(*a*) An upper section, enclosing the lower part of the arm, the elbow, and the upper part of the forearm ;

(*b*) A lower section, enclosing the lower part of the forearm and the hand ;

(*c*) A loop, or two loops, which should not consist of metal. I now invariably make them with a few layers of plaster bandage, held in position by an assistant until they have set ; around them a few more turns of plaster bandage are wound for the sake of strength and compactness.

If extension should appear necessary, it should be

effected by fitting a slide or screw connection to the plaster, such as is illustrated on p. 99. No appliances are more easily constructed than these.

Sometimes it will be well, when the fracture is exactly in the middle of the forearm, to support the dorsal aspect by means of a plaster rest 1 inch in width, connecting the two circular sections. The tendency to posterior sagging of the four fragments concerned may be avoided in this way.

In certain cases, continuous extension by a suspension apparatus may be employed with advantage. The sling should consist of strips fixed on a metal frame, as shown in fig. 80. Extension is applied to the lower third of the forearm. Counter-extension may, but need not necessarily, be applied to the elbow.

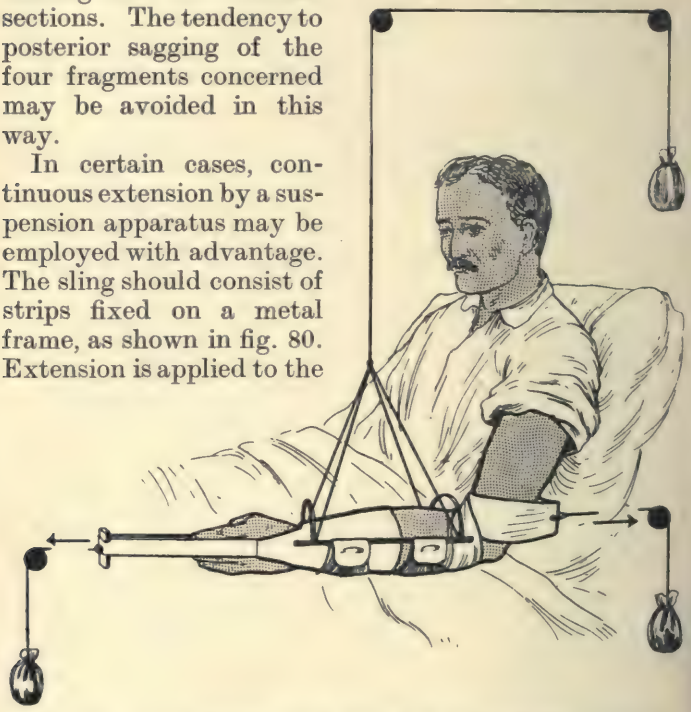


FIG. 80.—Immobilisation and continuous extension in a suspension apparatus. Extension by a weight of 800 grammes, counter-extension 800 grammes, counterpoising weight 1,200 grammes. For the sake of clearness, the hand is shown in semi-pronation, and not in supination.

A simple bracket fitted with two pulleys is used to suspend the sling. This is an excellent appliance.

As a rule, when esquillectomy has been performed promptly, these fractures get well without difficulty in forty or fifty days, leaving scarcely any trace of the injury, unless there has been irreparable damage to muscle.

In addition to the simple cases which have been studied there are other more complicated ones :

Apart from associated nervous lesions, which should be treated at once whenever intervention is undertaken at a really early stage, any of the following complications already alluded to may occur, according to the position of the fracture :

(*a*) *In fractures high up*, painful contracture of the fingers, due to irritation of the flexors. This usually appears at a later stage, and does not occur if the wound remains aseptic.

When it does occur, and the existence of true contracture of the fingers is established, the wound is first examined, and continuous extension is applied to the fingers. For this purpose, a rigid prolongation, of wood, plaster, or metal, should be fixed to the plaster, fitted with a pulley over which passes a traction cord pulling on an india-rubber loop passed round the fingers. This has always enabled me to effect a slow straightening of the fingers ; the method is less painful, and undoubtedly more effective, than sudden straightening by force, which causes injury, and is therefore dangerous.

This complication requires early treatment and careful attention, for the contracture gradually becomes more marked, straightening becomes more and more difficult, and ultimately correction by operation is necessary, the result of which is always doubtful.

(*b*) *In wounds in the lower part of the forearm*, involving tendons, the problem presented is totally different.

If the injury to tendons is not extensive and is easy to repair, and if the wound is disinfected at an early stage, tendon suture should be performed at once with all the care which this delicate operation requires.

On the other hand, if the laceration of tendons is very extensive, as, for instance, in bullet wounds associated with explosive effects, and if there is no certainty of ultimately producing complete asepsis of the wound, it is better to postpone tendon suture for the time being, and merely as far as possible to prevent complications in the immediate neighbourhood of the fracture. There should even be no hesitation in excising any sections of tendon which are completely destroyed and would eventually be eliminated. This is a matter for surgical common sense which cannot be expressed in formulæ.

6. TREATMENT OF CASES SEEN AT A LATE STAGE, OR ALREADY UNDER TREATMENT.—(*a*) *A case progressing well without operation.*—If there is no pyrexia and no suppuration, intervention is obviously not called for, and all that is necessary is fixation in good position (supination, with the hand flat), but continuous extension should be combined with this, and in such a case the looped plaster appliance should be replaced by one with sliding shafts, or with concentric cylinders kept apart by a spring. This fixation with extension should be continued for thirty to forty days. At the end of this time, it should be ascertained clinically and by X-rays whether union has occurred. If the bone is solid, cautious movements are begun; the limb is placed in the plaster again at certain hours and during the night for about twelve days. If the callus is soft, the limb should be carefully re-immobilised, since otherwise there is a danger of secondary curvature.

(*b*) *A case is seen in a septic condition.*—The region of the fracture must be completely cleaned at once;

as has already been said, sub-periosteal esquillectomy of both bones should be performed, the two inter-fragmentary gaps being reduced to equal dimensions. It is sometimes of advantage to smooth off the extremities with a saw, or at least to abolish marked irregularities, but in doing this, particular care should be taken with the periosteum, which should be kept well clear of the saw.

If tracks of pus are present, they should be widely exposed: the best method of preserving the muscles is to protect them from infection and from prolonged contact with pus. I cannot explain the lack of biological understanding in certain surgeons who permit sclerosis and atrophy of the muscles in order to avoid a cutaneous scar. It should therefore be remembered that the best means of avoiding extensive scars in these cases is to make a large incision in good time. If gangrenous fasciæ and necrosing tendons are exposed in this way, everything should be excised which is undergoing necrosis; it is no economy to leave in a wound tissues which must ultimately die.

It will be said that this requires experience, and this is true, as it is true of all surgery.

When the bony region has been surgically cleaned in this way, and the tracks of pus have been exposed, the wound should merely be plugged loosely with aseptic gauze, and the limb correctly immobilised while the sepsis diminishes. Suppuration quickly ceases, and the subsequent course is that of a fracture disinfected at an early stage. Occasionally, however, suppuration reappears to some extent after a time, and the edges of the wound become œdematous, but there is no constitutional disturbance. This is due to necrosis of a ring-shaped fragment at one or more of the bony extremities concerned; after gentle removal of these small and still adherent sequestra by means of forceps, suppuration ceases, and union is scarcely delayed by it. Union never fails to occur,

and speaking personally, I have never yet seen a pseudarthrosis of both bones of the forearm.*

During progress towards recovery, inflammatory contraction may develop, followed by cicatricial contraction of the flexors, causing the syndrome that has already been discussed.

This singularly troublesome deformity must be watched for and not permitted to develop or, above all, to become permanent.

I have already explained how it could be corrected by continuous extension of the fingers.

In the event of grave infection, amputation may become necessary; hitherto, I have always been able to avoid it by free esquillectomy.

(*c*) *A case heals with marked angulation or other vicious union.*—If union is recent, it is generally possible, under an anæsthetic, to rectify the position by hand.

On the other hand, if the callus is very resistant, the only resource is osteotomy, which should be performed at the original point of fracture.

There is often hesitation in performing osteotomy, because this is sometimes followed by a sudden and dangerous redevelopment of infection. In my own experience, there is nothing more easy than to avoid such bacterial recrudescence; it is merely necessary to leave the wound open, using no sutures, and plugging down to the bone surfaces.

With this method I have never yet seen osteotomies followed by serious infection.

Fixation of the hand in extreme pronation calls for the same operation. I have obtained good results from it.

(*d*) *A case is seen with radio-ulnar synostosis.*—This is unusual: up to the present I have only seen very

* Since writing this I have seen pseudarthrosis in a case which suppurated for a long period after inadequate esquillectomy and the elimination of several sequestra. Double osteosynthesis was necessary.

high radio-ulnar synostosis in the upper third of the forearm, the connection with one of the bones being very slight.

If the position is bad, as is usually the case, the hand being fixed in extreme pronation by counter-torsion, mere destruction of the synostosis will not restore normal movements. Moreover, it is a difficult operation, particularly in the upper part of the forearm, where the only possible approach to the synostosis, by a posterior incision, is complicated by the presence of the motor branches of the radial nerve.

The bone connection is always found to be much larger than it appeared in the radiograph.

In a case of this kind I have had great difficulty in attaining the desired result.

I therefore believe it preferable merely to correct the deformity by osteotomy and fixation by a Lambotte plate : I have obtained a very satisfactory result in this way.

FIG. 81.—Radio-ulnar synostosis. The ulnar lesion is inconsiderable, but the connection is twice as extensive as the radiograph indicates. This was broken down. It would have been simpler to perform osteotomy below the callus, and this would have given an equally good result.

(*e*) *A case is seen with a pseudarthrosis.*—This again is an unusual occurrence ; pseudarthrosis of both bones of the forearm is fortunately very exceptional, as this is a very troublesome condition. I have never seen it, and Nové-Josserand recently said that he had never operated on such a case. This is explained by the fact that pseudarthrosis is due to the impossibility of reducing the interfragmentary gap owing to the presence of the other bone in a healthy and therefore rigid condition.

Should it occur, the solution of the difficulty is double metal fixation, after suitable trimming; a double bone-graft is a very doubtful proceeding. The use of an external support slightly reduces the serious functional disorders caused by pseudarthroses, but it is only a makeshift.

C. Fractures just above the Wrist.

1. Anatomical Features.—These fractures are exceptional, as only one epiphysis is usually injured. They are characterised by comminution of the lower epiphyseal ends of the radius and ulna. Fissures pass upwards into the shaft, but in my experience the cartilage of the wrist-joint is usually intact and fissures into the joint do not occur.

Fig. 82.—Epiphyseal radio-ulnar synostosis with pseudarthrosis of the radius, following extra-periosteal esquillectomy. Power of pronation and supination is lost, but the hand is well- and rigidly supported.

The injury is always more extensive in one bone than in the other; the radius, being more exposed, is almost always the more seriously injured.

The frequent association of serious tendon and nerve lesions should be noted.

2. Physiological Features.—There are few of importance, at least in the early stages: scarcely any displacement occurs, because there is little muscular action to effect it; counter-torsion due to the action of the pronator quadratus is possible, but is not constant.

From a general point of view, there is a prospect of serious interference with function (loss of pronation and supination, associated injuries to the median and ulnar nerves, and to tendons).

3. Course.—This fracture is extremely serious, unless immediate disinfection is practised. Infection develops readily in the cancellous tissue of the epiphyses, sometimes spreads to the carpus (even when fissures are not present), but in particular almost invariably extends along the tendons and their sheaths : hence the phlegmanous suppuration which is only too often followed by amputation.

In those exceptional cases which progress well without esquillectomy, the orthopædic and functional result is generally deplorable ; the hand, through want of attention, becomes fixed in a vicious position (extreme pronation) ; further, owing to the unequal size of the two interfragmentary gaps, lateral deviation of the hand is produced, the latter being forced over on the side of the shorter bone by the longer. These are incurable deformities, of which lamentable examples may be seen in the Physiotherapy departments at the base.

I have never seen pseudarthrosis of both bones, but I have met with a curious case of radial pseudarthrosis compensated by radio-ulnar synostosis (fig. 82).

4. Indications for early Treatment.—There is only one: double sub-periosteal esquillectomy must be performed as quickly as possible, the two interfragmentary gaps being reduced to roughly the same dimensions, unless the loss of bone is more extensive in the ulna. Pseudarthrosis of the ulna low down interferes so little with function that it is practically negligible ; it is therefore sufficient to ensure union of the radius.

Sometimes the clearance will end by leaving only a thin layer of cancellous tissue on the upper surface of the radio-carpal cartilage. This need cause no alarm ; if no fissures are present, and, in particular, no infection, an uneventful recovery will follow, without reaction on the joint.

In operating on the radius, the medullary canal

should be examined carefully in all cases; on several occasions I have found fragments of the coat-sleeve firmly ground into the bone that could not be detached without energetic curetting. I need not insist on the disadvantages of leaving such structures in the bone.

Technique.—The esquillectomy is effected through two lateral incisions, situated, if possible, on the dorsal aspect. In the case of the radius, this possesses the advantage of avoiding the radial artery, and further, it is easier to preserve intact the external column of the styloid process, which is frequently uninjured. Lastly, it allows of more convenient fixation.

FIG. 83.—Fixation in a position of semi-pronation by means of a plaster trough.

After an aseptic dressing has been put on, fixation is effected by a palmar support, similar to that used after resection of the wrist. It should permit the wound to be attended to without the limb being removed from the plaster.

Assuming the almost certain loss of pronation and supination, the limb should be immobilised, if not at once, certainly later, in a position of semi-pronation with the thumb vertical.

As a rule the subsequent course of the injury is uneventful, and healing occurs without suppuration.

If this is the case, it is decidedly advisable to perform any necessary tendon or nerve suture at an early stage. The wound is, as usual, packed with gauze, and as a rule the result obtained is surprisingly excellent.

In my experience, union occurs in about fifty to sixty days.

5. Treatment of cases seen at a later stage, or already under Treatment.—(*a*) *A case progressing well.*—No operation should be attempted, but strict immobilisation, with the thumb vertical, is required. After X-ray examination, dead splinters and foreign bodies, if any are present, should be removed.

Fig. 84.—Explosive effects from a rifle discharged in the near vicinity of the forearm; wound seriously infected; total sub-periosteal esquillectomy on the third day obviated the apparent necessity of an amputation.

(*b*) *A case arrives in a septic condition.*—The temperature is high and the forearm and wrist are red and swollen. The exact topography of the injury is determined from a radiograph, very careful total esquillectomy is performed, and the medullary canal and the cancellous tissue of the epiphysis, particularly that of the radius, are cleaned with a curette.

Tracks of pus, if any are present in the region, are laid widely open, and all necrosing tissue is excised. Tendon suture should not be attempted at this stage, the only object of the operation being to save the hand, even at the expense of ultimately sacrificing fingers which, owing to irreparable injury to their tendons, will henceforth be a useless hindrance.

In this way amputation can be avoided even in the worst cases, and a hand preserved with some at least of its fingers useful. Esquillectomy, in fact, with excision of necrosed tissues rapidly arrests infection, and thus preserves tendons which would be destroyed by prolonged suppuration. An extensive operation

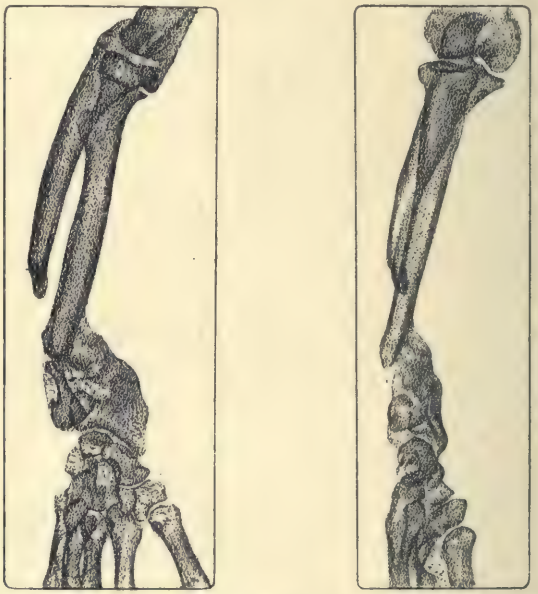


FIG. 85.—Anatomical result three months later of esquillectomy (see fig. 84): solid callus without osteitis; healing complete a month previously. Flexion and extension of the wrist normal, supination very limited. Finger movements almost normal, except in the last two, in which flexion is poor.

is the only truly conservative method, and I cannot too strongly recommend it.

During the first few days fixation is effected merely by means of an iron wire splint, the wound being dressed daily until a marked reduction in the sepsis occurs. When suppuration is totally arrested and the

appearance of the wound is favourable, which will usually be the case in eight to ten days, less frequent dressing is necessary. At this stage it is best to make a posterior plaster trough enclosing the palm and passing round the base of the thumb. The hand is immobilised in semi-pronation, the thumb directed upwards, and the elbow flexed to a right angle (fig. 83).

The plaster extends upwards as far as the middle part of the arm, and not farther downwards than the lower palmar fold, in order to allow of flexion of the fingers.

The plaster is removed for each dressing, that is, every seven or eight days, which is very soon possible when the operative disinfection has been well carried out.

Union usually occurs in two to three months.

If esquillectomy should fail and grave sepsis develop, amputation is unavoidable, but I have always found the former operation sufficient.

II. FRACTURES OF THE RADIUS ALONE

Two varieties are to be distinguished :
Fracture of the shaft proper,
Fracture of the lower epiphysis.

A. Fracture of the Shaft.

1. Anatomical Features.—The fracture is usually comminuted, but obviously all varieties are possible. As a rule, there are no radiating fissures.

Serious injury to tendons is almost always associated with this fracture. The extensors are more or less destroyed. In fractures of the distal part of the shaft, all the dorsal tendons of the thumb (the long abductor, the short extensor, and the long extensor) and the two radialis tendons are frequently severed ; injuries to the radial artery and the superficial branch of the radial nerve are equally frequent.

2. Physiological Features.—The upper fragment usually remains in position; it is only displaced in fractures of the upper end of the shaft, when the biceps pulls it forward (*i.e.* flexes it).

On the other hand, in all cases, whatever the position of the fracture, the supinating action of the same muscle comes into play, and, reinforced by that of the supinator brevis, supinates the upper fragment.

The lower fragment invariably undergoes inward displacement towards the interosseous space, owing to the action of the pronators. In fractures of the middle of the shaft it almost always comes into contact with the ulna. Hence there is lateral displacement, in the form of angulation, opening outwards. Similarly, the same muscles induce more or less marked pronation, and complete counter-torsion by rotating the lower fragment on its own axis, in a direction opposite to that of the upper fragment.

The final result is that the fragments correspond neither anatomically nor physiologically, which interferes with union and destroys the essential function of the forearm.

3. Course.—Fracture of the shaft of the radius, unless caused by a short-range bullet, and therefore marked by very extensive injury to muscle and tendons, is very unlikely to prove fatal. The situation of the bone being superficial, fractures due to shell-fragments may not give rise to any immediate and serious septic phenomena. The fact remains, however, that infection is practically constant, and will at least cause necrosis of splinters, which are gradually eliminated and destroy bone-forming tissue. This explains the frequent occurrence of spontaneous pseudarthrosis, apart, of course, from pseudarthrosis due to badly performed esquillectomy.

Further, the functional significance of tendinous lesions increases if the wound suppurates; an injury to a tendon that could be repaired after aseptic

healing of the wound becomes incurable when infection causing necrosis of the fragile extremities finally destroys a considerable proportion of the length of the tendon.

Lastly, a fracture which originally seemed quite mild may become a very serious affair if prolonged suppuration causes extensive muscular sclerosis.

The functional prognosis therefore depends on early disinfection of the fracture ; it is; in fact, essential to the future safety of the hand that these fractures should not suppurate. Asepsis is a necessity from another point of view : the complex arrangement of muscular origins in the forearm necessitates perfect reduction and strict subsequent fixation, and to induce and maintain these conditions satisfactorily in spite of prolonged suppuration is a difficult matter.

If none of this is effected, fracture of the shaft of the radius is equivalent to mutilation : the forearm becomes fixed in extreme pronation, with marked radio-ulnar dislocation ; the muscles and tendons destroyed are definitely and permanently lost, and the hand is an impotent, clumsy, useless, and painful appendage.

But this is not all : the contraction of the infected soft parts in the neighbourhood of the fracture, the natural tendency of the muscles to pull the lower fragment upwards and inwards, and the loss of bone caused by the elimination of splinters and destruction of their periosteum, diminish the length of the radius, and accentuate its original deviation deformity. The callus perpetuates this vicious position, and the two bones of the forearm are no longer in harmony ; the ulna tends to adapt itself to the dimensions of the radius by bending and causing a curved projection on the internal surface of the forearm, but this is insufficient to compensate for the diminution in length of the bone with which it is connected ; its styloid process appears to be displaced from the carpus and encroaches

on the base of the hand, which it appears to be forcing outwards. This, however, is only an appearance. In reality the hand follows the radius, to which it is more closely attached, outwards with the lower fragment of that bone. This displacement is due to the upward and inward movement of this part of the shaft, and in this way very troublesome radial deflection of the hand is produced. In itself, and altogether apart from any musculo-tendinous lesion, or counter-torsion, this deformity interferes considerably with the movements of pronation and supination.

Nor should it be regarded as a rare occurrence. In different degrees it is very frequent, and this frequency necessitates certain treatment which will be discussed later.

In short, fracture of the shaft of the radius, if infected or badly reduced, is liable to cause pseudarthrosis, damage to tendons, loss of pronation and supination, and outward deviation of the hand.

It is therefore not a fracture which can be regarded as a mild lesion.

4. INDICATIONS FOR EARLY TREATMENT.—As has been said, every effort should be made:

(*a*) To prevent suppuration;

(*b*) To induce and maintain reduction;

(*c*) To ensure that, after union, the shaft of the radius will be equal in length to that of the ulna.

This may be effected in the following way:

(i) *Asepsis is assured by early sub-periosteal esquillectomy;*

(ii) *Reduction by immobilising in the position of full supination;*

(iii) *Restoration of equality in length of the two bones by secondary resection of a small piece of the ulna, if the interfragmentary gap in the radius is rather wide.*

It may be thought that the third clause of the treatment is necessitated by the first, which causes a loss of bone-substance, and it will perhaps be said that if

adherent splinters were not removed and the radius were therefore not diminished in length, resection of the ulna would be unnecessary. But the objection is scarcely worthy of attention: the study of end-results, such as is possible at medical boards and orthopædic consultations, shows that radial deflection of the hand occurs very frequently in cases which have suppurated for long periods without having had an esquillectomy done, and in which, therefore, an interfragmentary periosteal callus should consequently have been most easily able to form. In actual fact, the best method of preventing diminution in length of a fractured bone is to facilitate osseous proliferation within the cylinder of periosteum, by performing a correct esquillectomy.

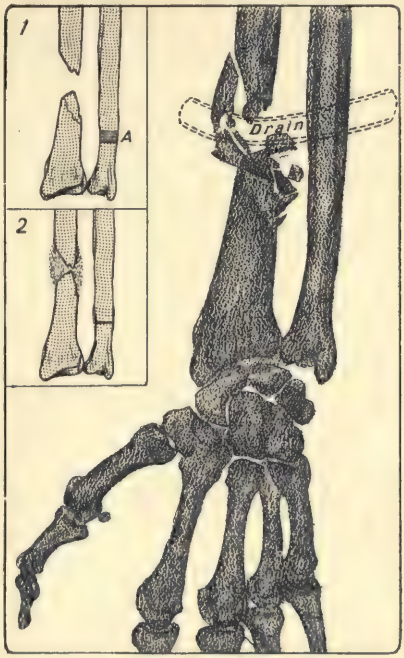


FIG. 86.—Fracture of the shaft of the radius by a shell-fragment, treated at the front by simple transosseous drainage. Serious infection; case complicated by fracture of the humerus. These two fractures were treated on the third day by total sub-periosteal esquillectomy. After six weeks union had occurred in the humerus, but not in the radius; tendency in the hand to outward deviation. I resected ½ inch of the ulna without interfering with the radius. Fixation by plaster (corrective) was followed by rapid union. Complete cure in three months, with all movements preserved.

After clearance, resection of the ulna is advisable if the interfragmentary radial gap exceeds an inch in length, not so much to avoid pseudarthrosis, which is unlikely to occur, as to ensure perfect harmony between the two associated bones. The physiology of the question shows that the radius and ulna being connected as they are, the slightest diminution in length of one of them causes dislocation of one of their joints, and consequent serious disorder of function. I have practised this resection of the ulna for several months past, and during that period have noticed a considerable improvement in functional recovery in the patients concerned.

5. TECHNIQUE.—*Esquillectomy* is effected by means of an external lateral incision, widely exposing the area of bone injury. The clearance should be strictly sub-periosteal, and in almost all cases, total; careful attention to detail is required. The flexors should not be disturbed from beneath, and as far as possible the wound should not be plugged from the internal side.

Reduction is easily effected by immobilising the elbow, forearm, and hand in a posterior plaster trough, the position being one of full supination, the palm of the hand being horizontal and facing upwards, and the hand inclined strongly towards the ulnar side. This plaster is retained or renewed until union has begun, which should occur in about eight weeks.

After four or five weeks, and after examination of radiographs taken from each aspect, the plaster is removed for investigation of the callus. If the interfragmentary space is rather wide (more than 1 inch), and particularly if the ulna is projecting a little on the internal aspect of the forearm, *about* 1 *inch of the ulna should be resected*. The best moment for this is the stage at which the callus, though still soft, is clearly visible in the radiographs as a darkish shadow in and around the interfragmentary space.

This resection, which should be strictly sub-periosteal, is conducted in the following way : a point should be chosen at some distance from the fracture, and the lower end of the ulna is ideal from this point of view. The bone is isolated with the rugine, the edge of which should be kept in close contact with the compact bone, in order to leave as much periosteum as possible in

FIG. 87.—Fixation in a plaster splint in a position of supination, the hand inclined to its ulnar side, after secondary resection of the ulna, following esquillectomy for fracture of the radius.

the wound. The entire circumference of the bone being well exposed, a chain or Gigli saw is passed round it, and a section of bone about 1 inch in length is excised. There need be no fear of removing too much ; in practice there is a natural tendency to be very economical and to remove too little. It is better, when possible, to fix the two fragments by means of a metal clip, wire, or Lambotte plate ; I have often,

however, dispensed with this. The wound is simply plugged and not sutured; the piece of bone removed from the ulna may be placed in the interfragmentary gap of the radius if this is wide enough. It is of advantage to re-expose the radial region, and to irritate it a little with the curette in order to stimulate bone-formation. The forearm is then immobilised in supination as before, with the hand deflected towards its ulnar side.

After this operation, the rapidity of callus-formation and the functional perfection attained are surprising.

This slight interference, in fact, absolutely prevents pseudarthrosis and deviation of the hand, and ensures maintenance of the anatomical conditions necessary for the recovery of pronation and supination.

6. THE TREATMENT OF CASES EXAMINED AT A LATE STAGE, OR ALREADY UNDER TREATMENT.—(*a*) *A case arrives after two, three, or four days, doing well.*—If there is no trace of infection, the fracture need merely be reduced and immobilised in supination in a posterior plaster. In this exceptional case, in which the absence of infection abolishes the necessity for esquillectomy, all efforts should be directed to ensuring functional recovery. After what has already been said, it is unnecessary to emphasise the importance of placing the forearm in supination, and of verifying reduction by a radiograph. If signs of slight infection should appear later, and splinters are eliminated, it should be decided by clinical and radiographic methods whether the length of the ulna should be reduced as a precautionary measure, since otherwise an originally benign fracture might finally produce deplorable functional effects.

(*b*) *A case is seen in a septic condition.*—Subperiosteal esquillectomy and drainage should be performed at once; total clearance is almost always necessary, and particular care should be exercised in separating the periosteum.

Fixation is effected during the first few days by a simple trough for the forearm. At the end of seven or eight days, when the infection has been arrested and suppuration has almost ceased, a temporary interrupted plaster should be made, the position being one of supination. This type of appliance has already been described (fig. 79).

It is often useful to increase the rigidity of the exposed part of the forearm by incorporating a small wooden splint in the outer part of the dressing, which acts as a rigid external support. It is applied to the internal aspect and fixed firmly in place by a bandage. There is a natural tendency to angulation of the bones, when a plaster of this kind is used which does not immobilise by any means perfectly, and this tendency is well counteracted in the way described.

This appliance is merely temporary. As soon as the wound need only be dressed at long intervals, it is preferable to immobilise in the usual plaster trough. Frequently, in cases such as have been described, precautionary resection of the ulna should be performed. Its indications have already been given: if the ulna tends to adapt itself to a diminished length by curvature, if the radiograph shows obliquity of the radio-carpal line and distal radio-ulnar diastasis, and if the interfragmentary gap exceeds 1 inch in width, I believe it perferable to have recourse to this without waiting for actual deviation outwards of the hand to take place.

(*c*) *A case is seen with a sinus.*—This is the ordinary case of fistulous osteitis, and the usual treatment is required.

(*d*) *A case is seen with vicious union in a position of extreme pronation.*—This position is extremely troublesome, and seriously interferes with the functions of the hand. It is due, as has been explained, to double rotation in opposite directions of the two fragments of the shaft, which incorrect fixation has failed to

rectify. This vicious disposition must be broken down to permit a second reduction of the fracture.

In this connection, two possible cases must be considered:

1*st Case. The callus is regular, and not fistulous.*—The bone as a whole, instead of possessing a curvature with a convexity outwards, forms an angle the apex of which is close to the ulna. The best course is to fracture the lower fragment at some distance from the callus. An osteotomy is therefore carried out below the fracture, and the small incision required for this purpose is not sutured, since plugging and drainage are effective in stimulating ossification The forearm is at once immobilised in a posterior plaster trough in a position of supination. After verification by a radiograph, the appliance is kept in place for at least a month. At the end of this period the plaster may be removed and the wound dressed. Fixation should, however, be prolonged for a further fortnight or three weeks in order to obviate a return to semi-pronation by torsion of the soft callus. The results of this operation are excellent; I have succeeded, in two cases, in reproducing almost normal conditions.

2*nd Case. Fistulous osteitis, with a large callus.*—Suppuration must first be arrested and complete cure obtained; the method described in the preceding case should then be adopted.

(*e*) *A case is seen with pseudarthrosis.*—Unlike pseudarthrosis of the ulna, that of the radius has serious effects: extreme pronation is induced in the lower fragment, the supinators being unable to counteract this; the hand is deflected outwards and is impotent; there is dropped wrist and inability to grasp with the fingers. The curvature of the ulna, due to its disproportionate length, is painful. Intervention is a necessity.

If the gap in the bone is not more than ½ inch in width, direct osteosynthesis by plate or clip is possible,

after removal of the intervening fibrous tissue and trimming of the extremities of the bone. But this does not correct the deviation of the hand, and the ulnar curvature remains. Even in these cases I prefer, after trimming the radius, to resect from the ulna a sufficient length of bone to bring about perfect reduction; union in the radius then follows very rapidly.

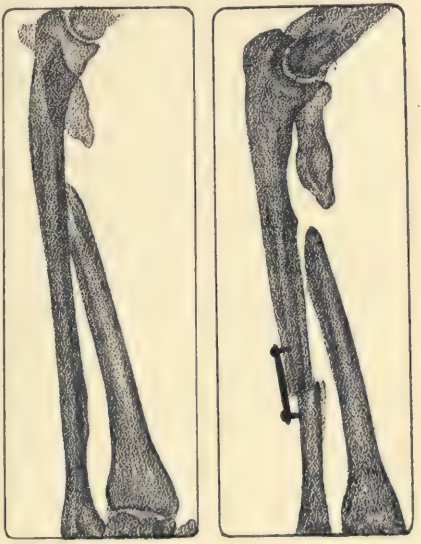


FIG. 88.—Fixation of the hand in extreme pronation following a seriously infected fracture of the radius, cured with a pseudarthrosis. Reduction under an anæsthetic was impossible. Correction of the vicious position was obtained after osteotomy of the ulna. The result is excellent. The hand is semi-pronated with the thumb upwards, small movements sufficient for professional purposes being still possible. The result dates from ten months previously.

When the gap is more extensive, there is no alternative to ulnar resection, but the ulna should be fixed at once by a clip or plate, as has been advised by Nové-Josserand. If this precaution be not taken, cure of the radial pseudarthrosis will often follow, while the surgical fracture of the ulna fails to unite. Nové-Josserand has quoted cases of this. I myself have been obliged in two cases to plate the ulna again when union had already occurred in the radius.

By this method consistent results will be obtained

in all cases where the width of the interfragmentary gap does not exceed 1½ inches. The same cannot be said of grafting, which many surgeons have attempted with few successful results: apart from its serious technical difficulty, account should be taken of suppuration, the main cause of its failure, to which it is rendered liable by the presence of latent organisms in the bone and soft tissues. I have seen six cases at medical boards in which the graft had been eliminated or reabsorbed.

Bone-grafting can therefore not be recommended as a reliable method in war-surgery. Consequently, when the procedure previously described (trimming of the radius and resection of the ulna) is not possible, the problem is difficult to solve.

In a case of pseudarthrosis in the proximal part of the bone, I obtained satisfactory results from simple corrective osteotomy of the ulna, which permitted restoration of the hand to a good position. The result, which dates from ten months ago, has been maintained (fig. 88). The pseudarthrosis is not cured, but the vicious position of the hand is corrected by what may be described as therapeutic counter-torsion.

Lastly, if there is very extensive loss of bone, the best solution appears to me to be inferior radio-ulnar arthrodesis, as described by Nové-Josserand, or the production of radio-ulnar synostosis low down, suggested by Ombrédanne.

B. Fracture of the Lower Radial Epiphysis.

1. Anatomical Features.—Small splinters with irregular extremities are frequently formed, their long axes corresponding to that of the bone; the articular surface is usually intact, and frequently the external surface, which forms the prolongation upwards of the styloid process, is also left uninjured; the epiphysis is partially broken up, but the fracture,

which is rarely complicated by fissures, usually remains extra-articular.

The splinters frequently remain in place, arranged in parallel formation, and separated by fissures; the appearance of an epiphysis thus composed of segments in juxtaposition is very characteristic.

There is almost always association of serious injury to tendons, and often laceration of the radial artery.

2. Physiological Features.—Little muscular action is exerted on the lower fragment, which usually remains in place, merely inclining slightly upwards and inwards without causing any dorsal prominence. I have always found it in pronation, either because the hand was in this position when the injury occurred, or owing to continued action of the pronator quadratus. The upper fragment assumes a position of supination, except in cases where the fragments are, so to speak, entangled, which sometimes occurs.

The study of a few fractures by bullets causing punctiform wounds proves the reality of this counter-torsion: I have twice found cases which healed without suppuration, and were cured with the hand fixed in extreme pronation; not the slightest degree of supination was possible, in spite of complete integrity of the joints (including the lower radio-ulnar joint).

In actual fact, the displacement of the lower fragment upwards and inwards is of much greater ultimate importance. Its actual result is to shorten the radius, causing outward deviation of the entire hand, and consequently serious future functional disturbance.

3. Course.—As a rule, serious local infective phenomena develop rapidly, and their intensity depends on the extent to which the projectile, in traversing the cancellous tissue of the epiphysis, has ground into it fragments of the sleeve, or, as frequently happens, soil. These foreign materials are also found beneath and between the tendons. Gas gangrene and similar

infections do not develop, since there are no muscles in the region. Tracks of pus develop along the tendons, beneath the skin, which is swollen and tense, and the progress of the infection soon outstrips the possibilities of surgical interference; the forearm is little more than a purulent sponge, giving rise to constitutional disturbance which multiple incisions are powerless to arrest, and amputation may eventually be the only resource. Even if the infection is successfully controlled, the muscles undergo sclerosis, tendons are eliminated or destroyed, the hand remains purplish and œdematous, and function is irremediably lost.

FIG. 89.—Union of an intra-epiphyseal fracture of the radius, with formation of a central cavity; upward displacement of the lower radial fragment, hand deviated to the radial side; considerable interference with movement. Orthopædic resection of the ulna was indicated, and would have avoided this.

Earlier intervention is therefore necessary: the situation may be controlled by an operation on the bone at a very early stage, but even in this case the tendons are too often destroyed, and the fingers remain stiff and almost useless.

In less serious cases, chronic infection of the fractured region destroys the marrow of the epiphysis; the callus which forms is large and peripheral, concealing a central cavity which remains fistulous for a long period.

Further, sepsis having caused necrosis, not only of the splinters but of the extremities of the epiphysis and shaft, the bone, already shortened by the passage upwards of the lower fragment, is very much reduced in length, and the callus renders this shortening permanent. At the same time, deviation of the hand occurs, and ultimately, when the wound has healed,

the surgeon is surprised to find serious outward deflection of the hand.

It is absolutely necessary to obviate these unfortunate occurrences and to ensure a good recovery of the injured region.

4. INDICATIONS FOR EARLY TREATMENT.—The following steps should be taken :

(*a*) Early operative disinfection of the fracture, which will ensure asepsis, and therefore easy maintenance of a satisfactory reduction ;

(*b*) Fixation in a suitable position ;

(*c*) Early operative correction, preventive if necessary, of external deviation of the hand.

Immediate disinfection is effected by sub-periosteal esquillectomy at an early stage, which, judging by my own experience, should in this case be total. This is a delicate operation, since the splinters are small, and their periosteum is very thin and adherent, as in all epiphyseal regions.

The fracture is approached by a dorsal incision, in addition to which a palmar incision will often be necessary, even at the expense of sacrificing the radial artery.

The epiphysis and medullary canal of the shaft should be scraped out with great care ; a large number of small fragments of bone pulverised by the impact will usually be brought to light in this way. The tendons should be carefully examined, and it is for this examination that a palmar incision is particularly necessary ; surprise will often be caused at what is found in contact with them.

This process of cleaning completed, it will usually be found well to remove a certain amount of bone from the dorsal surface of the epiphysis, rather than leave the latter in the shape of a completely empty shell. This should only be done after careful removal of the periosteum with a rugine.

Immediate repair of the lacerated tendons will often

be possible; it should preferably be effected with catgut.

The wound is then plugged with aseptic gauze, and the forearm immobilised by a plaster trough in a position of semi-pronation, the thumb upwards, and

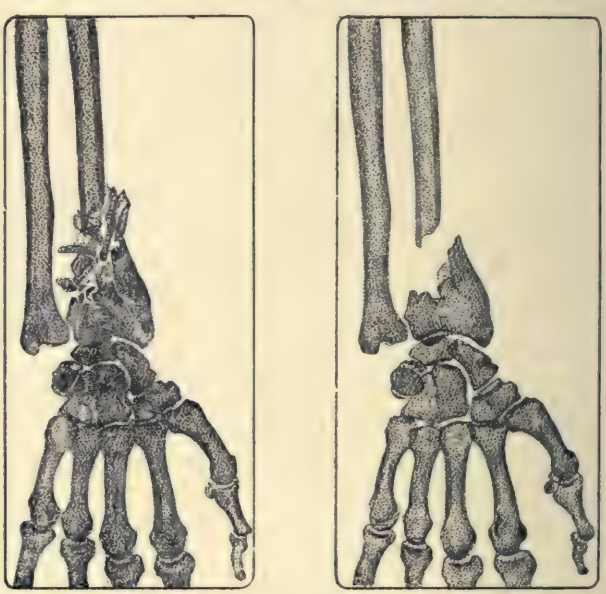


FIG. 90.—Fracture of the lower end of the radius, evacuated from the front after having a drainage tube passed through the epiphysis (without anæsthetic); wound seriously infected. Total esquillectomy during pyrexia on the third day; a number of pieces of clothing removed from close contact with the cancellous tissue of the epiphysis and the medullary canal of the shaft. Saline dressings, followed by aseptic dressings. Cure without pseudarthrosis in three months.

the hand supported on its ulnar side. During the first few days I believe that this position is preferable to that of supination, which renders the examination and dressing of the wounds much more difficult.

Fixation should first be effected by a metal splint,

then, at the end of some days, by a plaster trough, applied to the ulnar side of the forearm and reaching well above the elbow.

At the end of four or five weeks an X-ray examination is made. At this stage the shadow of the periosteal cylinder will usually be clearly visible, indicating that callus is in process of formation. The position of the styloid process of the ulna and the direction of the radio-carpal line must also be examined closely. If the styloid process seems to be situated lower down than it should be, if it descends lower than the styloid process of the radius, and if the radio-carpal line is directed obliquely upwards, preventive resection of about half an inch of the ulna, followed by plating of the latter, should be performed without delay (see p. 195).

After the operation, the forearm is immobilised for five weeks in the position of supination, unless the radiograph shows injury to the radio-ulnar joint. In this case, semi-pronation with the thumb upward is preferable as a permanent position, since it would be hardly reasonable to expect recovery of the power of pronation and supination.

5. TREATMENT OF CASES EXAMINED AT A LATE STAGE OR AFTER PREVIOUS TREATMENT.—(*a*) *A case is progressing well after some days, without operation.*—There is no pyrexia or suppuration; all that is necessary is immobilisation in full supination for a month, the hand resting on its ulnar side, in order to counteract the tendency to upward and inward deviation of the lower fragment, and therefore to prevent displacement of the hand. A plaster trough is the best fixation appliance for this case, and in many cases it should be left in position for more than a month, union in epiphyseal fractures being sometimes very slow.

(*b*) *A case arrives in a septic condition.*—After determining the existence and position of splinters and foreign bodies by means of a radiograph, total sub-

periosteal esquillectomy should be performed immediately. The epiphyseal cavity and medullary canal are cleaned with the greatest care, tracks of pus are followed to their limits, and necrosed tissue is excised.

After a comprehensive operation, a hypertonic saline dressing is applied to the wound, and fixation effected by a trough splint.

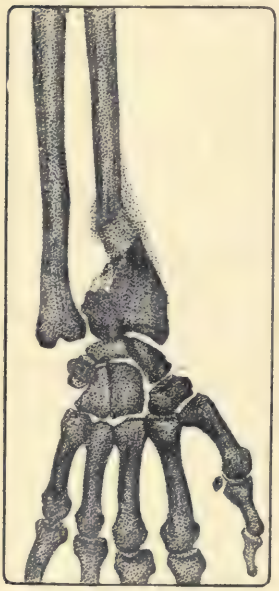


FIG. 91.—Radiograph after two and a half months. Cf. figs. 89 and 90.

The wound should be dressed daily, if necessary under an anæsthetic (ethyl-chloride). Any necrosed débris or small fragments of bone which have been overlooked are removed with forceps. If pus has tracked upwards, this should be drained, not with drainage tubes, but by incising the skin over the affected area. Sepsis will usually be arrested in five or six days. This method has up to the present always accomplished my object; I have never been obliged to amputate in such a case, even in those that have first come under my care at a late stage in a seriously septic condition, and I have never lost a case of this kind.

(*c*) *A case is seen with a sinus.*—This almost invariably leads to a cavity in the interior of the epiphysis, in which are enclosed splinters which were not originally removed; their removal, and scraping of the cavity is usually not enough to effect healing. The cavity must first disappear, and this habitually necessitates a levelling-down of the bone.

(*d*) *A case is seen with a pseudarthrosis.*—In this

case there is usually outward deviation of the hand. The styloid process of the ulna forms a marked prominence in an abnormally low position. In order to effect a cure, the extremities of the radius must first be trimmed, and all fibrous tissue between them excised; the ulna is then shortened to a sufficient extent to correct the radial inclination of the hand,

FIG. 92.

FIG. 93.

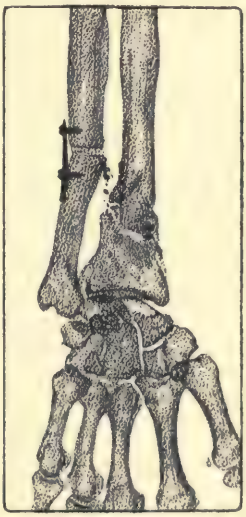


FIG. 94.

FIG. 92.—Radial pseudarthrosis with club-hand after fracture by bullet, never operated upon.

FIG. 93.—The same case seen from the side.

FIG. 94.—Cure after trimming of the radial extremities, resection of half an inch of the ulna, with application of a Lambotte plate.

and at the same time to approximate the two fragments of the radius. The two fragments of the ulna are united by a clip or plate, and the section of the ulna removed is placed in the interfragmentary gap of the radius. The ulnar wound is closed, the radial wound plugged. Careful immobilisation in the correct position, prolonged for about two months, will enable

union to take place, if a sufficient length of the ulna has been resected. There is a tendency to exercise economy in this connection, leading to failures which could well have been avoided, as occurred in one of my own cases. On the other hand, I have twice been successful with the procedure: in one of these cases an autoplastic graft had previously been introduced and reabsorbed without suppuration.

III. FRACTURES OF THE ULNA

I shall only deal with fractures of the shaft of the ulna; fractures of the olecranon are articular fractures, requiring sub-periosteal esquillectomy if there is no other fracture present * and re-resection if there is associated fracture of the neighbouring epiphyses. Fractures of the styloid process are comparatively trivial; after prompt esquillectomy, they heal rapidly and leave no functional disability.

Fractures of the shaft proper require separate study.

1. Anatomical Features.—These fractures, in contrast with fractures of the ulna in civil life, are generally not complicated by dislocation of the upper extremity of the radius. It is easy to understand why.

All types are possible, but the most usual in my experience is the type involving one large short fragment: a wedge-shaped mass is detached, and rarely more than two or three small splinters are present on the other side of the shaft. On the other hand, the projection of small fragments into the medullary canal is not unusual. Associated injury to the ulnar nerve occurs in a fairly large number of cases.

2. Physiological Features.—It is a constant

* In very favourable conditions it would be perfectly possible, after early operative disinfection, to treat certain fractures of the olecranon as peace-time fractures, but this can only be done in a quiet sector, where the possibility of close supervision is guaranteed. In the event of large numbers being admitted or evacuated, any form of bone-suture is definitely contra-indicated.

feature that the upper fragment remains in position, while the lower is displaced outwards by the powerful muscular action of the pronator quadratus, which forces it towards the shaft of the radius, with which it frequently comes into contact, and difficulty is sometimes experienced in reaching it unless the hand is placed in supination.

3. COURSE.—This is not a serious form of fracture;

FIG. 95.

FIG. 96.

FIG. 97.

FIG. 98.

FIG. 95.—Fracture of the ulna by a shell-fragment with fissures of the shaft; slight infection. Radiograph on the fourth day.

FIG. 96.—Radiograph eight days later, after sub-periosteal esquillectomy.

FIG. 97.—Radiograph three weeks after esquillectomy. The fissures are no longer visible.

FIG. 98.—Radiograph on the thirty-fifth day when healing of the soft parts has been complete for a week; post-operative course had been aseptic. (See the ultimate result, fig. 26, p. 54).

owing to the superficial position of the ulna, the area of the fracture is naturally exposed, and it is only in fractures high up the bone beneath the thick flexor muscles that serious infections occur.

As a rule, infection merely gives rise to a local affection of the bone, necessitating incisions and drainage, and ultimately leaving traces of its existence in the form of a cavity in the bone, enclosing a few small sequestra.

It is not rare for pseudarthrosis to follow suppuration in these cases. It is true that pseudarthrosis of the ulna is not a serious inconvenience, but that is no sufficient reason for not avoiding it. A further danger is that of injury to the flexor muscles, as was discussed on p. 179.

4. INDICATIONS FOR EARLY TREATMENT.—Here, as in other regions, sub-periosteal esquillectomy is so reliable a guarantee against asepsis, that if there is an accompanying injury of the ulnar nerve, this should be sutured at once. The fracture is approached by a lateral incision, the flexor muscles being displaced by a retractor if the level of the injury necessitates this. Clearance consists in separating the large short fragment with a rugine as well as the few small isolated pieces of bone found in the region of the fracture. The medullary canal is gently cleaned with a small curette and the cavity left is plugged with gauze. Fixation is effected by a posterior plaster splint, the forearm being supinated, with the hand flat and the elbow flexed.

In general, the subsequent course is uneventful, and union occurs in thirty to forty days. It is well to keep on the plaster rather longer: interrupted appliances and continuous extension are useless.

5. TREATMENT OF CASES FIRST SEEN AT A LATE STAGE OR AFTER PREVIOUS TREATMENT.—(*a*) *A case arrives going on well.*—Fixation of the forearm in supination is all that is necessary; a posterior plaster trough is applied for this purpose.

(*b*) *A case arrives in a septic condition.*—Immediate sub-periosteal esquillectomy is essential: the whole region of the fracture is cleaned through a fairly long lateral incision, all splinters being separated with the rugine and removed. During this process the condition of the flexor muscles should be carefully examined, as small splinters are frequently found in them and may give rise to prolonged suppuration

which has a serious effect on muscular contraction and causes grave functional disorder. At the same time all devitalised fascial tissue should be removed.

This treatment, if carried out with sufficient attention to detail, and

FIG. 99.—Narrow sub-articular pseudarthrosis of the ulna, following early extra-periosteal esquillectomy. The wound healed very rapidly, but there was no regeneration of bone. The continuity of the ulna is provided by a narrow osseous band, in contact with the shaft, but not united to it. All movements are possible and almost normal.

FIG. 100.—Removal of the lower two-thirds of the ulna by extra-periosteal resection performed at the front. The patient was cured very simply, and there is virtually no disturbance of function; pronation and supination are performed well, but the forearm is weak: a leather wristlet is useful.

not merely as a rapid draining process, will be successful in arresting infection and safeguarding the functions of the hand, which would be permanently

and seriously jeopardised if prolonged suppuration took place in contact with the flexors and their tendons. If in the course of treatment flexion of the fingers is seen to occur, continuous elastic traction should be applied without delay to correct their position and prevent serious cicatricial contracture (see p. 179).

(*c*) *A case arrives with a sinus.*—The sinus almost invariably leads into a small cavity, in which is a small sequestrum embedded in granulations. Hypertrophic callus and extensive formation of sequestra do not occur in the ulna, frequent as they are elsewhere. This is not surprising, when the usual type of fracture of this bone is considered. But it should not be supposed that it is sufficient to remove the osseous débris and scrape the walls of the cavity in order to cure the sinus. In these cases I have always found the medullary canal blocked on each side, forming a closed cavity which is a frequent cause of subsequent trouble. If a cure is to be assured, it is absolutely necessary to clear the cavity completely, cut down the bony walls of the cavity, and reduce the infected area to a smooth and regular surface. This done, rapid cure will be effected without the use of antiseptics. If necessary, sub-periosteal resection of the infected section of bone may be performed.

(*d*) *A case is seen with pseudarthrosis.*—In general, a pseudarthrosis of the ulna causes little functional disability of the forearm and hand. In the lower part of the bone it is only slightly troublesome, and if the patient wears a leather wristlet, he may be said scarcely to notice it. In the upper half of the bone it causes little inconvenience. If the loss of bone is extensive (1½ inches), slight curvature sometimes occurs, due to the weight of the hand when the forearm is raised, but this is not a constant feature. My impression, based on the observation of three cases, is that even more extensive loss of bone (3 to 4 inches) causes no more trouble (fig. 100).

In fact, the disorder in function is not usually sufficient to justify intervention. I have seen a dozen of such pseudarthroses or gaps in the bone without operating on one of them. This confirms the opinion of Nové-Josserand, who advises refraining from operation, even in the severer forms.*

* A. Broca, in his recent book on the osteo-articular sequelæ of gunshot wounds, is of the same opinion (see "The After-effects of Wounds of the Bones and Joints," by Prof. Aug. Broca, Military Medical Manuals, University of London Press).

CHAPTER V

MULTIPLE FRACTURES OF THE UPPER LIMB

The early disinfection of fractures by sub-periosteal esquillectomy is never more urgently required than in the numerous cases which occur of multiple fractures caused by fragments of an exploding shell. By careful cleaning of all the wounds, which will frequently amount to a somewhat lengthy operation, surprising results may be relied on if this be done as a primary or even as a secondary measure.

Further, it can be laid down as a principle, that when muscles, arteries, and nerves are not destroyed to such an extent as to render subsequent use of the limb totally impossible, amputation should not be performed for multiple fractures. It is better to ensure a favourable course for the fractures by multiple sub-periosteal esquillectomy, since much may be expected from periosteal regeneration.

The immediate fixation in these cases can only be effected by a large trough splint : Delorme's flat trough is very suitable from this point of view. A satisfactory

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Fig. 101.—Fracture of the humerus with intra-medullary missiles, fracture of the radius and ulna, of the fourth and fifth metacarpals, and of the metacarpal phalanx of the fourth finger. Multiple wounds by shell-fragments on the upper limb and thorax ; infection of all the wounds. Intra-febrile sub-periosteal esquillectomy on the fourth day, three fingers being removed owing to the extent of the lesions of the soft parts. Later, sub-periosteal resection (nineteenth day) of the lower extremity of the ulna. Result obtained after two and a half months ; wounds almost completely healed, fractures united. The periosteal reproduction of the lower extremity of the ulna will be noted. Manual correction of the flexion of the humeral callus was possible.

FIG. 101

appliance may be built of wide wooden slats the length of the limb, extending from the shoulder to the tips of the fingers.

As soon as possible, however, a suspension apparatus should be employed. Cure may certainly be effected by other methods, and the case of which radiographs are reproduced (fig. 101) was kept for the whole period of treatment in a Delorme trough.

A suspension appliance, however, obviates pain ; it is also more convenient for dressing and may be

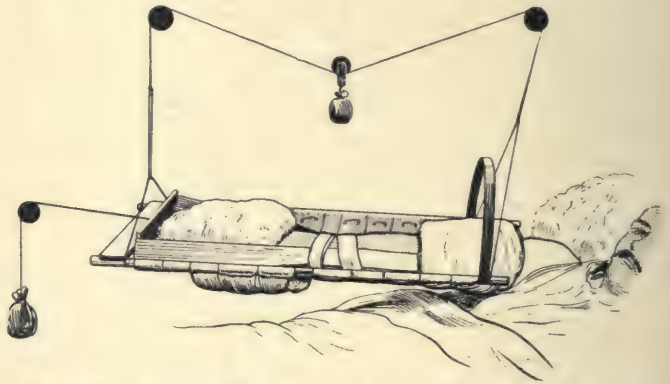

FIG. 102.—Continuous extension on the arm and wrist in a suspension appliance, for shattering of the humerus and radio-carpal fracture. Esquillectomy was performed in the case of the humerus ; the wrist was resected. For some days continuous extension was made on the hand, the bands being fixed to the stirrup of the humeral extension. Weight of extension, 1,500 grammes ; counterpoise weight, 4 kilogrammes. (The frame is not illustrated.)

combined with continuous extension. In short, a better result is obtained at less inconvenience.

Two types of suspension apparatus may be used : the type in which extension is applied to a horizontally suspended limb (fig. 102), or another in which the arm is extended horizontally and the forearm vertically (fig. 65, p. 152). Experience leads me to recommend the latter from all points of view.

The arm is placed in a hammock with continuous horizontal extension applied above the elbow; the forearm is flexed and suspended at right angles; traction is exerted on the palm of the hand or on the fingers, if the wound is very low down, but on the proximal part of the wrist if possible. Patients readily become accustomed to this: I have two in course of treatment at the present time for double lesion, and both fractures are progressing as uneventfully as could be desired.

I have frequently treated fracture of the humerus, radius, ulna, and metacarpus in the same patient. These cases gave more trouble than the two of which I have just spoken, and the superiority of suspension fixation seems to me to be beyond discussion.

CHAPTER VI

FRACTURES OF THE FEMUR

THREE main varieties are found in practice :

1. Sub-trochanteric fracture.
2. Fracture of the shaft proper.
3. Supra-condylar fracture.

I. Sub-trochanteric Fracture

1. ANATOMICAL FEATURES.—There is almost invariably comminution, the largest splinters rarely exceeding 2 inches in length; frequently the violence of the impact forces them far into surrounding muscles and into the medullary cavity, fragments often being found in contact with the sciatic nerve, or even within it ; I have personally removed them on two occasions from the nerve trunk.

The end of the shaft, as well as that of the upper fragment, are usually jagged and irregular, but not fissured. I have never seen cracks running up into the thickness of the trochanter or to the neck, and I believe it to be very exceptional for fissures to produce an articular fracture even in an extensive injury of this kind.

There is very often considerable muscular damage, whether the skin be lacerated or not ; in some cases the femoral vessels are injured by the projectile, and the sciatic nerve is often torn or severed.

2. PHYSIOLOGICAL FEATURES.—Muscular action displaces the upper fragment in an invariable and

characteristic way: the muscles, passing from the pelvis to the trochanter, the psoas, iliacus, and pectineus, displace it upwards and outwards, and it assumes a position of abduction, flexion, and external rotation.

On the other hand, the lower fragment, under the influence of the adductors, is carried upwards and inwards, and to a certain extent is internally rotated. Its displacement upwards is sometimes such that it appears to be riding over the upper fragment; in any case splinters may be found behind the latter, a point that it is well to remember from the operative point of view.

As a matter of fact the displacement of the upper fragment is the more important, and gives the distinguishing feature to this common type of fracture (fig. 103).

3. COURSE.—Sub-trochanteric fracture is a very serious injury, which often leads to death within a few hours from simple shock, or by secondary infection unless this danger is met by early operative treatment.

In cases which run their course with only a mild focus of infection, a large bony callus is formed, enclosing sequestra which are difficult to find, and whose removal does not always bring about closure of the sinuses.

On the other hand, unless the fracture is reduced with a careful eye to its physiological features, union may fail entirely, or may occur with marked deformity and serious shortening.

If, however, the fracture is treated by early and thorough operative disinfection which preserves the elements essential to the formation of bone from the periosteum, and if an intelligent reduction is performed in time, perfect structural and functional recovery occur, the patient suffering no deformity and very little shortening. I have in my wards two men suffering from this variety of fracture: one got up after fifty-seven days, the injury being completely sound, the

other after eighty-two days. In each case the callus allowed of their lifting the thigh at the end of forty-two to forty-five days. The shortening does not exceed half an inch.

4. INDICATIONS FOR EARLY TREATMENT.—In subtrochanteric fractures serious symptoms usually appear immediately; the patient suffers from great shock, from which it is very difficult to rouse him.

Moreover, owing to the difficulty of transport, cases are often not seen until they are in a seriously septic condition. Consequently it is more true of fractures of this region than of any other, that immediate operations are the exception.

In cases of shock, immediate operation is impossible; it would prove fatal by augmenting the shock. In the absence of more precise theories by which to direct the ideal treatment of shock, every effort should be made to counteract the peripheral vaso-constriction: with this object the patient is kept warm, and lying down with the head low, complete repose is induced by an injection of morphine, and camphorated oil and adrenalin are used as stimulants.

In a few hours' time the operation may be performed; it should be rapid and merely do what is urgently required, leaving complete esquillectomy to a later stage. In any case, the shock does not render amputation preferable to esquillectomy; *it only indicates an operation in two stages.*

What should be done if shock is not severe?

Extensive muscular damage and the existence of arterial lesions only rarely contra-indicate a conservative operation. This being so, the best course is usually to trim the cut muscular surfaces thoroughly with scissors, to sacrifice all contused soft tissues, and to tie all bleeding points: ligature of the femoral artery has no untoward effect on the fracture.

If, however, the extent of muscular injury is really too great, if there is a large hematoma and infiltration

of blood far along the thigh, and if the limb below is purplish and cold, amputation cannot be deferred. It should be a flapless section at the level of the fracture according to Pauchet's method, the upper fragment being roughly smoothed off, subsequent trimming of the stump being necessary. Amputation is less drastic than disarticulation, and is always preferable to it.

In short, the original operation, apart from certain exceptional cases (diffuse arterial hematoma, extensive injuries to soft parts), can generally be limited to prophylactic sub-periosteal esquillectomy.

5. TECHNIQUE.—Esquillectomy should be performed through a long external and slightly anterior incision ; this incision at the site of election is always preferable to those corresponding to the wounds of entry and exit, which lead to drainage in the vicinity of blood-vessels, or in positions only accessible with difficulty for the purposes of dressing.

When the deep fascia is incised, the edges immediately come together and close the wound, so that there is difficulty in exposing the injury thoroughly with retractors, and there should be no hesitation in making transverse incisions in the fascia lata, so as to produce a widely-open wound, distinctly more extensive than the area of the fracture. After particularly careful cleaning of the soft parts, and removal of foreign bodies, sub-periosteal esquillectomy should be performed on the usual lines. Cleaning of the medullary canal and the cancellous tissue of the upper fragment should not be omitted ; in several cases I have found splinters embedded high up in the cancellous tissue of the trochanter. There should be no fear of operating too drastically : experience shows that surgeons never go to too great lengths, and too easily fail to explore adequately, which accounts for subsequent suppuration. The entry and exit wounds are freed, their internal surfaces being completely excised. The usual aseptic gauze dressing is applied.

The most delicate part of the treatment now arrives, that of immobilisation.

Immobilisation.—If possible (*i.e.* unless large numbers of urgent cases are being received, or immediate evacuation is necessary), these cases should always be treated by *continuous extension in a position of marked abduction*. Any fixation appliance not fulfilling these two essential conditions can only be provisional, *e.g.* an appliance for transport; it should not be used for treatment.

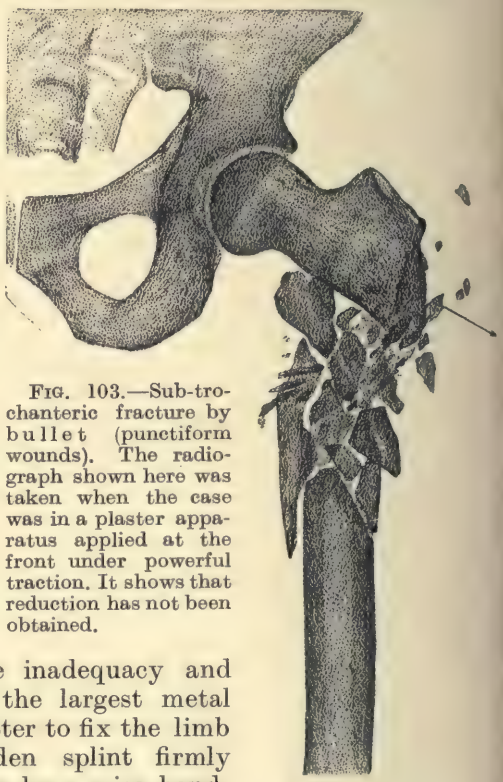

FIG. 103.—Sub-trochanteric fracture by bullet (punctiform wounds). The radiograph shown here was taken when the case was in a plaster apparatus applied at the front under powerful traction. It shows that reduction has not been obtained.

I imagine it is unnecessary to insist on the inadequacy and danger of even the largest metal troughs: it is better to fix the limb on a long wooden splint firmly fixed to the pelvis by a spica bandage. This method of fixation is more complete and less painful.

Plaster, particularly in the form of a pelvi-dorso-pedial splint, immobilises well and diminishes pain, but cannot affect reduction of a displacement; to correct this, even powerful traction under an anæsthetic is

insufficient. In several cases I have seen immobilisation effected by a large plaster well constructed under continuous extension, but in no case was reduction of the displacement obtained (see fig. 103). This should cause no surprise when the magnitude of the muscular forces exerted on the two fragments is considered. There is, however, a more important reason for this failure than the resistance afforded by muscular action; it is the *direction* of the displacement of the trochanteric fragment, over which we have no control. It is therefore necessary to bring the lower fragment into line with the upper, in other words to abduct the thigh to 45° to 50°, according to indications given by a radiograph. The best position cannot always be obtained at once; it is sometimes necessary to feel one's way and to alter the direction of the traction. Under these conditions a permanent rigid appliance, even when applied with the aid of the X-ray screen, is unsuitable, and a rigid appliance is an unsatisfactory means of treating sub-trochanteric fractures. It is excellent for transport and temporary

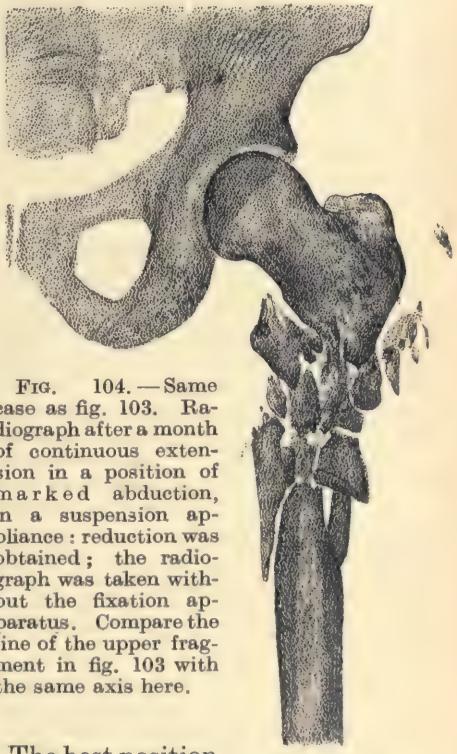

FIG. 104. — Same case as fig. 103. Radiograph after a month of continuous extension in a position of marked abduction, in a suspension appliance: reduction was obtained; the radiograph was taken without the fixation apparatus. Compare the line of the upper fragment in fig. 103 with the same axis here.

fixation, but it is not justified in any other circumstances. Sub-trochanteric fracture should therefore be treated by continuous extension in marked abduction. For this purpose the *suspension apparatus* is the ideal. Details of its construction will be found on p. 251; for the present I am dealing only with essential points, and with those which are peculiar to sub-trochanteric fractures.

FIG. 105.—Suspension appliance: continuous extension in abduction. Traction of 8 kilogrammes. For the sake of clearness the curved bars connecting the side wires of the splint frame are not represented. Compare with figs. 115 and 117.

Two uprights support a horizontal bar 6 ft. 6 in. above the floor level. The support is placed in the

necessary position, as indicated in fig. 105. It is well to make it of considerable length.

The wire splint frame is suspended from the horizontal bar, and consists of two thin iron rods, about 36 in. long, $\frac{1}{2}$ in. wide, and $\frac{1}{8}$ to $\frac{1}{6}$ in. thick, connected at each extremity by a curved metal bridge, which is bolted to them. Holes are drilled at the ends of the horizontal rods to receive the suspension hooks.

As described on p. 104, lengths of linen are pinned to this frame to form a sling-hammock.

After operation, the limb is placed in this cradle, which is suspended by cords from two pulleys, arranged as shown in fig. 105.

A weight of 4 to 5 kilogrammes is usually required as a counterpoise ; this is a weight sufficient to make the splint with the limb in position remain in equilibrium in any desired position. The angle of inclination of the splint may easily be regulated by moving the central pulley supporting the weight.

Continuous traction is exerted in the usual way, *i.e.* by means of a stirrup of adhesive strapping, passing up the limb and fixed, not (as shown in fig. 105, for the sake of clearness) by circular strapping, but by bands wound spirally round the limb. A weight of $3\frac{1}{2}$ kilogrammes is used at first, increasing by 500 grammes daily, until it has reached 7 or 8 kilogrammes.

The right-angled position of the foot is maintained by means of a small padded board, which is strapped within the frame of the cradle.

Progress after operation.—Dressing is usually a simple matter, and is performed without disturbing the patient ; the wounds being usually clinically aseptic, dressing at long intervals, which is very desirable during the first few weeks, is almost always possible.

As a rule, healing is rapid, and is complete in fifty to sixty days. Sometimes after the fortieth day the patient is under the impression that his limb is solid. I have seen a patient lift the thigh and move it in all

directions at the end of thirty-two days. No reliance, however, should be placed on this apparent proof of solidity; the callus is still soft, and extension and fixation must be kept up for a further long period, or

FIG. 106.

FIG. 107.

FIG. 106.—Sub-trochanteric fracture by a shell-fragment after secondary sub-periosteal esquillectomy (twelfth day).

FIG. 107.—Radiograph on the sixtieth day, showing: (1) reduction by continuous extension in abduction in a suspension appliance, and (2) the periosteal callus, obtained in forty-eight days.

the callus is liable to become bent and give rise to marked angular deformity. This has occurred recently among my own cases (see figs. 107 and 108), and for this reason I emphasise its importance. I consider an

immobilisation of 100 to 120 days necessary. But long before this the limb can usually be restored to its normal position; in about fifty days the callus has a sufficiently firm hold on the upper fragment to influence its position and to maintain reduction if continuous traction is maintained. This should be verified by X-ray examination.

At this stage the patient may with advantage get up, using Delbet's walking appliance, which is described on p. 261.

The results of treatment conducted in this way are excellent: the shortening is not usually more than ½ to 1¼ in.; movements of the knee are gradually regained after two or three months of massage and active movements. In short, there is almost complete recovery of function in less than six months, and it is not unusual to see patients able to resume normal

FIG. 108.—Secondary flexion of the callus on the seventy-sixth day, the patient having begun to walk on the seventy-second day. The action of the pelvi-trochanteric muscles has come into play, when the abduction extension was removed. The same apparatus was reapplied and the correction of the deformity was obtained without difficulty, the final result being practically identical with that in fig. 107.

life during the second six months after being wounded.

6. Treatment of cases seen at a later stage, or after previous Treatment.—(*a*) *A case has progressed well without operation.*—The treatment indicated is simply immobilisation, for which purpose the best appliance, as in other cases, is the suspension and traction apparatus described above.

Within a short time, however, Delbet's appliance will be useful, and will allow the treatment to be carried on as long as may be necessary.

It should be remembered that in non-infected comminuted fractures, as for instance those caused by a bullet with punctiform wounds (fig. 103), union, though sometimes very rapid (twenty-eight days in one case in my experience), is often, on the contrary, fairly slow. I have seen a case in which it failed to occur within seven months.

(*b*) *A case that may or may not have been operated upon, arrives in a septic condition.*—The patient may only have been brought in after lying out for a long time (as is frequently the case with seriously wounded and helpless men), and no immediate operation will have been performed. The thigh will be swollen and freely suppurating. Complete sub-periosteal esquillectomy should be performed immediately, as has already been described; there should be extensive removal of muscle, and the smallest bone-splinters should be carefully searched for, and adherent splinters removed, even if they extend for some distance down the shaft. The periosteum, irritated by the infection, will always form a solid column of bone in such cases, and the removal of 3, 4, or 5 inches of the bone may be undertaken without hesitation, if the surgeon will have sufficient patience to separate the periosteum carefully with the gouge. In these cases of secondary esquillectomy, the callus forms very rapidly (I have seen an interfragmentary gap 6 inches wide filled in

this way), as I shall describe in connection with fractures of the shaft proper.

(*c*) *A case is seen at a later stage of infection.*—The outlines of the callus have already appeared, but there is profuse suppuration. It would be extremely rash to undertake a complex operation in a deeply-seated region, which cannot adequately be exposed. Nothing should therefore be done beyond the removal of easily accessible sequestra, and no attempt should be made to clean the infected region completely. The policy is to avoid the spread of infection, and to limit the latter, with the intention of operating afresh when the stage of sinus-formation is reached. After the operation it will be found well to employ warm moist dressings for the first few days.

(*d*) *A case is seen with a sinus.*—A radiograph is absolutely necessary to ascertain the cause of the sinus and determine the treatment. Occasionally the case is found to be one of superficial osteitis, but almost always deep osteitis is responsible, originating frequently from a small sequestrum. In this case, promiscuous curetting is inadvisable, and indeed injurious. The diseased area should be localised very exactly, as a missile is localised, and a methodical search should be made for it, by the shortest route. The operation should always be performed on a comprehensive scale, otherwise there is not much likelihood of getting a good result.

(*e*) *A case is seen with a pseudarthrosis.*—Almost invariably pseudarthrosis is due to lack of reduction, but suppuration has rendered the osseous tissue sterile, and traction combined with wide abduction is not able to bring about union.

A cutting operation is necessary to excise the inter-fragmentary fibrous tissue, and to bring the fragments into apposition by a metal suture.

If possible, even at the cost of detaching the insertions of the pelvi-trochanteric muscles with a gouge

in order to permit easier movement of the upper fragment, the fracture should be reduced, and the two fragments placed end to end. Unfortunately this ideal can only rarely be realised; muscular and aponeurotic contractures and stiffness of the joint prevent effective action (a difficult matter enough apart from these considerations) on the trochanteric fragment. In a case of this kind I confined myself to fixing the shaft to the lower surface of the upper fragment by a large Lambotte plate. The result was good, in spite of a shortening of 2½ in.; the patient was able to walk again, after a year of absolute helplessness.

(*f*) *Vicious union is found to have occurred.*—There are numerous cases in which the result obtained must be accepted, mediocre though it may be; when, for instance, the radiograph shows an enormous mass of osteitic bone, intervention is very dangerous, and probably destined to complete failure.

If, on the other hand, the radiograph shows lateral union by a callus which is not too dense, and easily accessible, the question of fracture of the callus may be discussed, and of re-immobilisation in full abduction to reduce the deformity. But this decision should not be come to lightly; the operation is always difficult and doubtful in its results, and can only be undertaken in favourable cases.

After osteotomy of the callus involving as little injury as possible, the wound is left open, without suture, and simply plugged with moist gauze; if it is closed, recurrence of infection is to be feared even if drainage is arranged for, and the best means of avoiding all post-operative complications is to keep everything exposed, resisting the temptation to sew the wound up round a large drainage tube.

I am also of opinion that it is better not to correct the faulty position by sudden force; when the callus has been broken, existing conditions are allowed to remain, and continuous extension is exerted with the

lower fragment in its original position, without immediate correction. Progressive abduction to the necessary degree is effected gradually during the days following.

By this procedure in a case of this kind I obtained an excellent result without causing the slightest degree of pyrexia.

II. Fractures of the Shaft: the so-called Fractures of the Thigh

1. Anatomical Features.—There is extreme diversity of anatomical form in fractures of the thigh. All known types of fracture may be encountered; the most usual is the large-splintered type, more or less resembling the classical "butterfly-wing" fracture. An almost constant feature is the presence of one or two large longitudinal splinters, roughly diamond-shaped, and tapering to sharp points at a great distance from the actual seat of fracture; they often measure 6 inches and more in length, and are adherent by their periosteum to the muscles attached to them.

In the middle of the thigh there is often an internal fragment very adherent to the insertions of the adductors, and when it is separated with the rugine, the impression is produced that the larger part of the bone has been removed; in reality, the splinter amounts only to a narrow strip, the removal of which does not diminish the future solidity of the bone, if the periosteum has been preserved carefully.

Large and small splinters are often forced a great distance into the muscles.

The damage to the muscles is usually very considerable, but it is frequently situated beneath the scarcely lacerated deep fascia. A muscular hernia projects through a small unyielding opening in the fascia, and the wound appears inconsiderable, but if the fascia is opened up, the deep muscles are found

lacerated and destroyed, with areas of interstitial hæmorrhage well beyond the immediately damaged area; their ragged edges come together and form a rigid curtain closing in the region of muscular destruction, in which are splinters, clots, and fragments of the projectile.

Simultaneous injury to vessels or to nerves may occur, but is not common.

I have twice seen an irregular indirect fracture, situated at some distance from the splintered region (fig. 119).

2. Physiological Features.—Owing to the development and strength of the muscles surrounding the femur, there is virtually always displacement of the fragments in fractures of the thigh, and as a rule this is considerable. The forces, which are normally in equilibrium, are arranged in antagonistic groups; fracture destroys the equilibrium, and the fragments are displaced in the direction imposed on them by the group of muscles whose insertions are most completely preserved and whose action therefore inevitably becomes predominant.

There are five principal groups of muscles whose actions are dissociated by fracture:

The pelvi-trochanteric group, which acts on the upper third of the shaft, from the trochanter downwards, and causes outward rotation of the thigh, with abduction and slight flexion on the pelvis.

The adductor group, which comes into play when the fracture is obliquely directed from above downwards and inwards at the junction of the middle and lower thirds of the shaft; it adducts the upper fragment, slightly flexes it, and rotates it, either outwards or inwards, according to the condition of the lower part of the adductor magnus, which causes inward rotation. If the fracture occurs above this part of the muscle, its action is excluded, and external rotation occurs. This is usually the case, and results in torsion which causes considerable interference with walking, but less

serious trouble than would be caused by an uncorrected displacement in the opposite direction. This external rotation is not surprising, when the posterior plane of the adductor insertion is considered.

The long posterior muscle group (biceps, semimembranosus, semitendinosus) which normally flex the leg on the thigh. In fractures situated below the upper third, these contribute to the posterior upward displacement of the lower fragment and of the leg. This upward movement is never direct; there is always slight adduction or abduction due as much to the injury as to muscular action.

The muscular envelope formed by the quadriceps femoris which produces vertical upward displacement of the lower fragment.

The gastrocnemius and soleus which normally exert no action on the thigh, rotate the lower fragment backwards around the transverse axis of the condyles when the fracture is at the lower end of the bone; this, however, only happens in supra-condylar fractures with which we are not at present concerned.

It results from all this that the following displacements may occur in fractures of the shaft:

Marked *over-riding*, sometimes to the extent of 3 to 4 inches. This is due to posterior displacement upwards of the lower fragment, caused by the muscles surrounding and attached to it, and by the posterior muscles of the thigh arising from the pelvis.

Lateral displacement in a direction varying according to the position of the fracture. In fractures, in the upper third of the shaft, the pelvi-trochanteric muscles cause abduction and external rotation of the upper fragment, the lower extremity of which partially penetrates the muscles, and causes a prominence beneath the skin; there is therefore marked angulation, apex outwards, between the two fragments: the curvature which often persists after union arises in this way.

In fractures of the middle, and notably of the lower

third, of the shaft, an opposite displacement occurs: the adductors, whose insertions are generally intact, counteract the action of the pelvi-trochanteric group, or overcome it, and the upper fragment therefore remains in place or is adducted, while the lower is pulled outwards and upwards behind it.

A simultaneous *antero-posterior displacement*, due to flexion of the upper fragment on the pelvis and to slight rotation backward of the lower fragment caused by the calf muscles. As a result of this, the upper fragment is more or less markedly displaced forwards.

Rotation on the long axis of the bone, usually external, and principally due to the adductors, and to the weight of the limb.

It is of importance to emphasise the strength of the muscular actions which produce these displacements of the femur; it is such that no manual force can overcome it, and immediate reduction is impossible, even with anæsthesia. It should be remembered that muscular action is more powerful when the limb is extended in a straight line; *if the thigh is flexed on the pelvis and the leg is flexed on the thigh, muscular relaxation is immediate* and correction easier. The surgeon may easily verify this on himself, and after this simple experiment he will easily understand the physiological rules for reducing fractures of the thigh.

It should also be remembered that, as a rule, the contracting muscles carry with them splinters which are thus displaced in unexpected directions; no fracture yields more surprises during an operation than does a fracture of the thigh.

3. Course.—Many cases of comminuted fracture die rapidly from shock and hæmorrhage. The initial hæmorrhage is very alarming; no one who has not seen these cases when they are picked up can have any idea of the loss of blood. The first impression is that a serious vascular lesion exists, but this is generally not the case. Hæmorrhage, however, contributes

largely to the immediate danger in certain cases which do not often pass the first surgical line (*relai*).

Of the less seriously wounded cases which recover from the initial shock, the majority are liable to rapidly developing gas gangrene, diffuse cellulitis, or acute osteomyelitis, and these are fatal if the necessary intervention is not undertaken in time: difficulty in collecting the wounded gives time for infection to develop and greatly favours the severe and often fulminating forms of the latter. Other cases almost always exhibit secondary infection, which may call for the gravest decisions.

Thus the principle of early operation in cases for whom transport is impossible has become a dogma. But it is difficult to do just as much as and not more than is necessary. Superficial cleaning is always insufficient; esquillectomy limited to free fragments only does not prevent the development of acute infections and profuse and persistent suppuration, the outward sign of central osteomyelitis, the results of which are very serious; tracks of pus requiring prolonged drainage destroy the muscles; infection of the fracture area destroys the bone-marrow; finally, the irritated periosteum proliferates rapidly, and encloses diseased or dead fragments, just as the new bone in adolescent osteomyelitis invaginates sequestra (fig. 9, p. 27). The periosteal proliferation is almost always adequate to reproduce continuity of the bone, and pseudarthrosis in the shaft of the femur is rare, but a pathological callus is very common.

Moreover, owing to the gravity of the local phenomena of sepsis, and the difficulty of frequent and painful dressings, it is impossible to secure immobilisation in good position during a long period of suppuration; frequently the callus consolidates in a few days, leaving considerable deformity and shortening, and the orthopædic result is bad.

Meantime, the patient is obliged to remain in bed

and the knee becomes stiff and equinus develops; movements of the knee-joint are so limited that there is almost ankylosis, a fibrous ankylosis which will certainly deserve the name unless the condition is much improved by massage and movements.

In short, infected fractures of the thigh, generally because of inadequate esquillectomy, occasionally but rarely recover by the formation of a regular and healthy callus; sometimes the superficial surface of the latter is inflamed, owing to a small sequestrum, and is then easily curable; much more often there are sinuses; there is osteomyelitis, and union is bad; the patients, with muscles atrophied and joints stiff, remain liable to sudden recurrence of infection; the limb is still there, but function, if not completely lost, is at least considerably reduced in value.

4. Indications for early Treatment. (*a*) *Amputation.*—A conservative operation is not always possible in the thigh, and there are conditions in which the necessity for amputation must be recognised. Before sepsis is evident, these indications are not very frequent; they are furnished by the extent of the injuries to soft parts, the extent of injury to the bone, or by the intensity of the shock.

(i) If there is muscular destruction involving half the posterior aspect of the thigh, accompanied by severance of the sciatic nerve, or if the anterior muscles are non-existent over a wide area, amputation is, in my opinion, preferable to any attempt at preservation. Sepsis may be avoided, and its effects would not perhaps be very severe in these widely open wounds; but repair is almost impossible—a repair, that is, compatible with satisfactory function of the limb: the patient would become an invalid, and, what is more, an invalid with a painful wound. Hence a suitable amputation, leaving a stump consisting of such healthy tissue as remains, is often preferable to attempts to preserve the limb.

(ii) If the femur is badly comminuted, *i.e.* practically destroyed for 6 to 8 inches of its length, as is the case in certain wounds of an explosive type, the same remarks apply : the orthopædic result is too doubtful to justify either the trouble involved or the risk that will be run.

(iii) In cases which only rally feebly from their shock, in whom a rapid operation is desirable, and a long one is out of the question, amputation may be necessary to transform a lacerated into a clean dry wound which involves no organic strain during repair ; such a procedure makes for safety.

On the contrary, if there is an accompanying vascular lesion (of the femoral artery or vein), a conservative operation should be performed, after ligature of the vessels affected. It goes without saying that ischæmic gangrene of the leg demands immediate amputation.

On the whole, early amputation is only called for exceptionally. It is performed in the usual way, without sutures ; the flapless operation should be reserved for infected fractures.

(*b*) *Sub-periosteal Esquillectomy.*—Whenever a conservative operation seems possible, free sub-periosteal clearance is the only means constantly *and under all circumstances* to ensure the regular formation of a healthy callus, combined with clinical asepsis of the wound.

This operation is done, not to carry out an extensive resection of the shaft, but to explore the wound completely and remove anything which blocks it and converts it into a closed cavity, as well as any infecting foreign body, missile, fragments of clothing, free splinters, fragments of dead or devitalised tissue either near or within the bone—everything, in fact, that experience shows is destined to become gangrenous owing to contusion or infection. The interfragmentary gap should be clean, and it should be possible to apply a dressing direct to it without difficulty. In order to

effect this, any adherent splinters that conceal the medullary canal should be removed: if the surgeon knows how to use the rugine with patience, too much cannot be removed, since all elements necessary for repair are left in the wound.

I emphasise these fundamental points because their application is nowhere more necessary or more difficult than in the femur. This difficulty is due to the depth of the injury, to the bulk of the muscles surrounding the bone, and to the resistance of the fasciæ enclosing them, all of which points also explain the gravity of these fractures.

As far as possible, intervention should not be undertaken during the phase of shock; the patient is kept warm, and should receive an intravenous injection of adrenalin (0·5 cc. of a 1 in 1,000 solution) and ·01 gm. of morphine, while favourable developments are awaited. When warmth returns, and the temperature has become normal, and the blood-pressure has risen sufficiently (above 10 by Pachon's appliance) operative disinfection is carried out.

5. TECHNIQUE.—(*a*) *The Operation.*—The operation is performed under ether or spinal anæsthesia, after

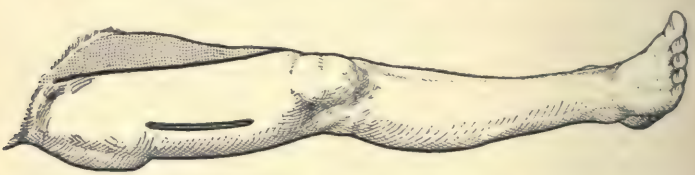

FIG. 109.—The shaded area indicates the region in which intervention should not be undertaken.

X-ray examination and localisation of foreign bodies if possible. The patient should be in a slightly inclined position, with the head low (to counteract the shock and bulbar anæmia).

When the dimensions of the existing wounds do not

absolutely force the surgeon to approach the fracture through one of them, an incision should be made *at the site of election*, that is, on the external aspect of the thigh. *The limb is slightly flexed on the pelvis in order to relax the obstructing muscles. This is of great importance.*

The wounds are first cleaned, and all contused, lacerated, or devitalised parts are widely excised. When the region of the fracture is approached, large retractors are introduced and the wound well exposed and freed completely from any foreign matter. A longitudinal incision is now made at the site of election with clean instruments. The incision should be external, rather than antero-external; anterior incisions are bad, because the scar in the muscles fixes the thigh in extension. The wound should be 4 inches at least in length, and its exact position will vary according to the situation of the wounds already existing. The fascia is incised for the same distance and also nicked transversely, since otherwise its tense edges cannot be separated satisfactorily, and tend to reclose the wound. The vastus externus is incised, bleeding points are tied, and the bone is reached. When the fracture is exposed, two large retractors are introduced, and the injury is examined.

Two conditions may be found: either comminution has occurred, or the fracture is of the long-splinter type.

In the former case, careful clearance with the rugine and forceps is required. Everything entirely free is removed with forceps, then, the wound being clean, the periosteum is separated with the greatest care from splinters which are loose, but still attached to the former. Some surgeons believe that in these cases it is impossible to attempt to preserve the periosteum, and that no one who had ever seen a comminuted fracture would suggest sub-periosteal esquillectomy. Their opinion is worthless, and merely proves that

they are poor operators, lacking in care and patience, and no value should be attached to these ready-made opinions. The fragments situated close to the ends of the shaft should first be located, and their periosteal covering will easily be detected; from this point it will be possible to strip the fragments completely, and when the operation is concluded, there will be the satisfaction of finding a clearly visible channel of periosteum, lacerated, it is true, but forming a resistant whole.

If the splinters are large, after removing those that are free, the periosteum is separated from adherent splinters which require removal, by grasping them firmly with forceps and carefully using the rugine upon them, cutting well down into the bone; this will preserve intact an invaluable periosteal sheath around the end of the shaft.

It is difficult to say exactly how far the removal of adherent splinters should be carried in the pre-infected stage: *it is scarcely ever necessary to remove all of them; it is necessary and sufficient that dressings should be able to be applied direct to the fractured region, after complete exploration of the latter.*

It is therefore an affair of judgment and experience. There is a general tendency not to remove enough, and much determination and experience are necessary to perform a sufficiently comprehensive operation and expose the region thoroughly.

After ligature of every bleeding point and careful cleaning of the whole wound, the gap between the bones, which is now of regular proportions, is loosely packed with aseptic gauze, and the wounds are left unsutured. A counter-incision for drainage is useless; I never make one, even in secondary esquillectomies, and I have never regretted it.

Fractures complicated by vascular lesions require no special treatment, other than the necessary ligature. In wounds complicated by injury to the knee-joint,

which are sometimes seen, missiles within the joint are first removed, the synovial cavity is closed, and the fracture treated independently as though it were the only lesion. Sencert has described a remarkable instance of complete success.

After an operation conducted with the intention of leaving nothing unexplored, the subsequent course of the case is constantly uneventful and aseptic; the dressing may be left untouched for ten, twelve, or fifteen days, and when it is removed, the wounds are found to be of a fine bright red colour. From this point onwards, if time is available for dressing the case daily, the wound may be left exposed to the air for some hours each day, and healing will be accelerated; if the time cannot be spared, dressing at long intervals is continued. With this excellent method I have seen union occur in fractures by the fourth dressing. Generally the patient will be able to lift his limb from the immobilisation apparatus between the fortieth and forty-fifth days. It will, however, be prudent not to allow him to walk alone until a hundred days have elapsed, in order to avoid the disappointment of bending the callus; active movements of the knee may, however, be begun early, and when the patient is finally allowed to get up, walking will be easy, the stage of crutches will be brief; I have seen patients ready for discharge towards the one hundred and twentieth day.

(*b*) *Fixation and continuous extension.*—(1) *The guiding principles.*—After operative disinfection of the fracture, *fixation and continuous extension constitute the two essential objects in treating all fractures of the thigh.* Asepsis demands good fixation; without the latter, continuous trauma infects different parts of the wound and increases the virulence of the organisms present. Continuous extension is the only means of restoring bone and muscle to normal positions, that is of reducing the fracture, which in its turn is the best way of ensuring immediate satisfactory progress, and

at the same time of safeguarding the future function of the limb.

How should these two necessary conditions of treatment be realised ?

Three principles should always underlie it :—

(i) *An immobilisation of the femur is not satisfactory unless the appliance is fixed to the pelvis, or buttressed against the projections of the latter, thereby uniting it with the femur.*

All the trough splints at present in use are thoroughly bad appliances for fixation, and their use should be permanently discontinued.

(ii) *Continuous extension is only satisfactory when the pull is exerted in the axis of the upper fragment.*

The displacement of the upper fragment should be studied in each case, and the extension adapted to it ; when these various displacements are considered (see p. 232), it will be understood that there are fractures in which the pull should be exerted in abduction (high fractures), and others in flexion on the pelvis (fractures of the middle third). There can therefore be no universal apparatus.

(iii) *To avoid useless effort and facilitate extension, the limb should always be placed in a position which naturally neutralises the displacing force :* the ideal realisation of this object is always to arrange the lower limb with the leg slightly flexed on the thigh, and the thigh on the pelvis. In this relaxed position, a much smaller force will effect a more rapid and complete reduction.

These are the general principles on which the treatment of fractures of the thigh should be directed. It is by reference to them that the innumerable appliances suggested for this purpose should be judged, and above all, it is by such reference that one should be chosen for any particular case. This book is not a general review of the subject, and I shall only describe my own idea of conducting the treatment in the

successive stages of the case, for there is no universal method of fixation and extension applicable everywhere; at each échelon of the Army Medical Service the appliance used should be different and adapted to local conditions. It is only in a base hospital where treatment will be continued until cure is effected that the ideal appliance can be realised.

(2) *The appliances used in the various Echelons.*—(i) *At the Aid-post.*—Temporary fixation should be effected by applying a long, well-padded wooden splint, from the iliac crest down the outside of the limb. This is fixed above by a spica bandage to the pelvis, and also by separate bandages to the knee and leg; a

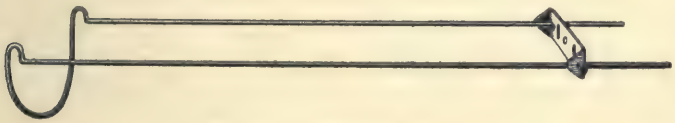

FIG. 110.—Blake's splint.

second splint is applied on the inner side. This rough method is far superior to the metal trough which is no more than a makeshift.

As a matter of fact, the ideal arrangement is the splint recommended by Blake. It is very light, consisting of two iron rods ($\frac{1}{2}$ inch in diameter) united by an oblique curved bar, which takes its purchase beneath the ischium. It can easily be slipped beneath the limb, which is slung in it by strips of bandage; an adjustable foot-rest connecting the lower ends of the side-rods renders it adaptable to all cases.

(ii) *At the Clearing-station.*—After operation, a continuous extension appliance should be chosen, which is not cumbrous, does not interfere with the personal hygiene of the patient, permits ready supervision of the limb, and can be quickly applied. It is also important that it should be possible to keep a stock of these.

If we imagine the working conditions to be those of an active ambulance unit, which is obliged to evacuate operation cases as soon as they can be moved, and not of a unit in a quiet sector, which keeps its cases until they are cured—acting, in fact, like a base hospital—three types of appliance are to be recommended: Sencert's appliance, Blake's splint rest, and the apparatus of Hey Groves.*

I do not include Pierre Delbet's apparatus in this list; it is adapted only for use at the base, and cannot be used in a busy ambulance, because, being difficult to apply, it requires time and careful attention. Moreover, the fact that it permits walking is of no advantage at this stage; for the fractures under consideration, walking appliances should be reserved for convalescent cases at the base.

It may happen that a unit possesses no continuous extension appliance; plaster of Paris is then the only resource. I shall describe the plaster appliance which seems to me best adapted to the circumstances.

(*a*) *Sencert's appliance* (fig. 111) consists of a sort of Hennequin's splint made by cutting to the right length one of those perforated metal sheets supplied to all ambulances. To the sides of this are nailed two wooden slats, the outer being 40 to 44 inches in length, the inner 32 to 34 inches and both 1 inch wide and $\frac{1}{2}$ to $\frac{3}{4}$ inch thick. The distal ends of these two slats are connected by a thin wooden cross-bar, and by a small rigid iron wire passing through the hole of a cotton reel; in the centre of the appliance another wooden bar is fixed transversely by screws which may easily be removed. A screw hook is fixed in this bar, carrying a wire triangle, through which passes a wide ring of rubber. The latter is simply a circular segment, 2 inches in width, of an old inner tube. Lastly, two

* Schiassi, of Bologna, describes an excellent appliance, in several ways resembling that of Alquier, which deserves to become known; it is very neat, and may be used during transport.

vertical pieces of wood, 7 to 8 inches in length, form a support for the appliance and are fixed at the lower end of the metal trough.

The following is the procedure for applying the apparatus: In the metal splint is placed a towel, and a quantity of cotton wool, in order to pad it well. After esquillectomy and dressing, the foot and leg are firmly bandaged up to the position of the dressing on the thigh. Immediately above the knee is placed a Hennequin's sling, through which the pull is to be exerted. The middle bar of the splint with its rubber

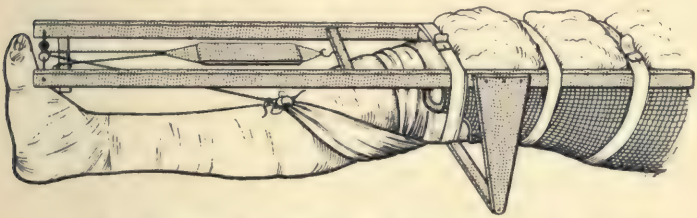

FIG. 111.—Sencert's appliance, which effects continuous extension and allows of transport.

ring is unscrewed, and the thigh is placed in the splint, the inner border of which should be brought up as close as possible to the ischio-pubic ramus, which brings the outer border up as far as the anterior superior iliac spine. The middle bar is then screwed in position. A cord fixed to the loop of the Hennequin sling passes over the reel acting as a pulley, and is fixed to the india-rubber ring, which is previously stretched: continuous traction is thus effected. Finally, a small wooden splint is applied to the anterior aspect of the thigh, which is intended to prevent antero-posterior displacement, and the towel originally placed in the trough is folded over the dressing. Three straps are used to keep the whole in position.

This appliance effects perfect extension, easily reducing the greatest displacements; further, it pro-

duces very effective immobilisation, and is satisfactory for long-distance transport. I have used it, and obtained excellent results. It has only one disadvantage: it cannot reduce the anterior displacement in fractures in which the upper fragment is directed forwards. In these cases an appliance is required which flexes the thigh on the pelvis. The surgeon may be satisfied with provisionally exercising direct pressure by a small wooden splint, as suggested by Sencert, but this should only be temporary; better results can be obtained with other appliances.

(β) *Blake's splint*, described above (fig. 110), is much to be recommended: it is convenient in use and the reverse of cumbersome, easy to apply, and an ideal appliance for ambulance work.

When it is applied to the limb, the latter may easily be suspended from the roof of an ambulance car by cords and a spring; it thus constitutes a treatment and a transport appliance at the same time.

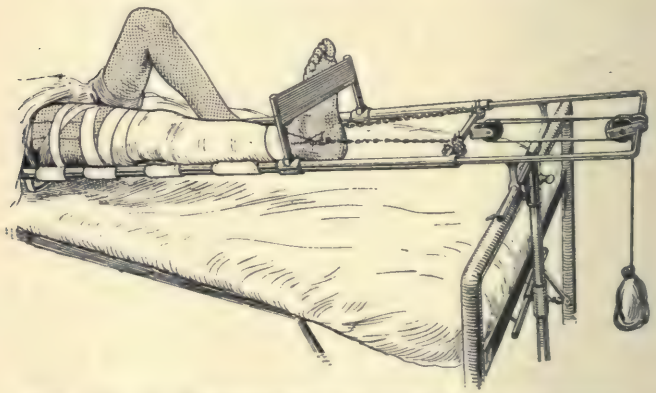

FIG. 112.—G. W. Hawley's continuous extension apparatus.

It may be modified to resemble G. W. Hawley's appliance, shown in fig. 112, which appears equally excellent.

(γ) *Hey Groves's splint* (fig. 113) is purely an appliance for treatment, but its convenience and real advantages should bring it into general use in surgical ambulances. Its object is to effect immobilisation by suspension with continuous extension by simple means, thus obviating the use of the cumbrous suspension appliances which render immobilisation by suspension difficult at the front.

By means of steel rods, ½ inch in section, two inclined planes of unequal length are constructed. The ex-

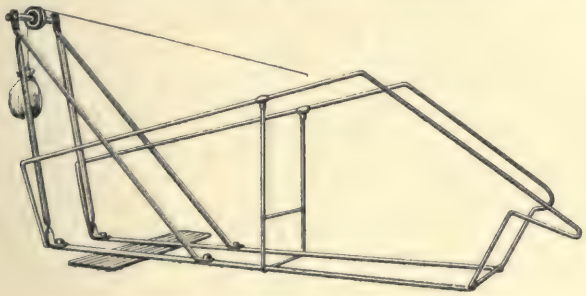

FIG. 113.—The Hey Groves apparatus.

tremities of the two rods are bent back and fixed to a steel frame.

A transverse metal plate ensures rigidity and serves as a fixation point for the vertical branches of the extension support. The suspension sling is made as usual with flannel bands. Hey Groves also recommends strips of rubber (pneumatic tyre inner tube) in the parts opposite the wounds, their elasticity acting as a counter-extension. The sling is padded, and the limb placed in it, with the knee opposite the angle between the two inclined planes, both knee and hip-joints being flexed; extension is applied above the knee in the usual way, the traction cord passing over a pulley (fig. 113). Steady traction on the thigh should be maintained while the appliance is being fitted.

This appliance has numerous advantages: it is not cumbersome; an ambulance unit can keep a large stock of them, the frames fitting one into the other; they are easily cleaned, even sterilised; they rapidly exert continuous extension in flexion, which is ideal in the majority of cases, counter-extension being effected by the weight of the limb; dressing and X-ray examination is easy, and painless transport is possible.

(δ) *Plaster appliances.*—All kinds of circumstances necessitate the use of plaster, *but a plaster appliance should never be anything but temporary*, to be replaced as soon as possible by a continuous extension appliance, leaving the limb freely exposed to the air. Undoubtedly, numerous forms of plaster appliance have been suggested, which effect continuous extension by means of lacing, or of shafts and springs resembling those in Delbet's appliance, but these are only mediocre appliances, whose application occupies a great deal of time, and whose therapeutic effect is decidedly inadequate, because within a short time their immobilisation is no longer good, because they imprison the tissues, and because they do not afford the choice of a good position for traction. I need not emphasise this last disadvantage after what I have written above on the point.

Granted that they cannot be used for treatment, plaster appliances should be as simple as possible: their sole object is to afford a good fixation until the apparatus best suited to the case can be applied; for this purpose the best plaster is the dorsal pelvi-pedial rest, described in Vol. I, p. 127, for post-operative immobilisation after resection of the hip (see figs. 62 and 63, Vol. I).

It consists of two plastered portions forming a T with unequal branches: the pelvic limb covers the antero-lateral part of the pelvis, being applied over the iliac crests and the hips; the other is moulded as a trough on the anterior aspect of the thigh, leg, and foot,

and the limb is as it were suspended by a roller bandage fixing it.

Bosquette has very successfully modified this splint by maintaining rigidity in the region of the thigh simply by two strips of sheet iron, with the result that the wounded region is freely exposed, being merely crossed by these narrow connections, which do not interfere with dressing, and, being reinforced, are very resistant. The diagram below (fig. 114) shows the

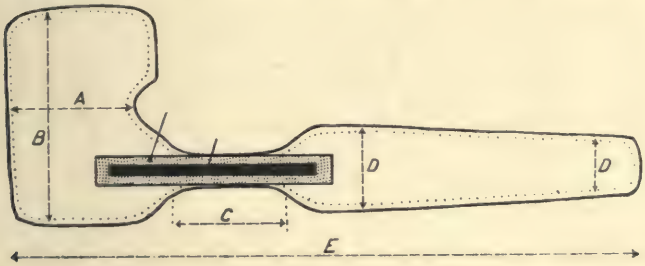

FIG. 114.—Dorsal pelvi-pedial plaster support, with reinforcing sheet-iron slats (Bosquette's model). (A) Distance from the pubis to the xiphoid cartilage; (B) Semi-circumference of the trunk at the level of the umbilicus, increased by 8 in.; (C) Length of thigh occupied by the dressing; (D) Semi-circumference of the limb; (E) Total length, from the level of the xiphoid cartilage to the base of the toes, following the curvatures of the limb. The appliance consists of twenty thicknesses of tarlatan, and the reinforcing slips ten thicknesses; the dotted lines indicate the seams. Only one connecting slat is shown, and the reinforcing support. The apparatus usually consists of two slats and three supports.

exact construction. I have several times received cases immobilised in this way: they had had no pain during transport, and the fragments were kept rigidly in position, without, however, being completely reduced. *This easily constructed apparatus seems to me the best existing type of plaster appliance for the first few days, and for transport.*

(3) *For transport*, no form of trough should be used; they are painful, and the injury is increased by continuous trauma: their supply to the Medical Service

should be stopped. In place of them, one of the following may be used: Sencert's appliance, Blake's splint, or Bosquette's type of the dorsal pelvi-pedial plaster.

(4) *At the base hospital*, after dressing, X-ray examination, and slight further operation if necessary, when the direction of the displacement has been

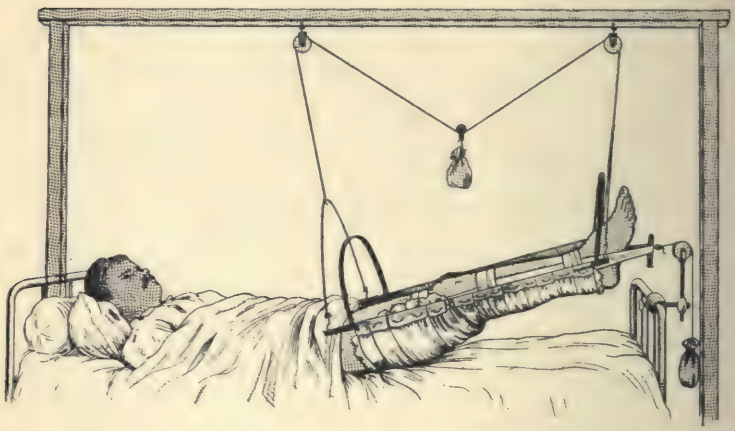

FIG. 115.—Suspension apparatus for fracture of the thigh, much simplified and easily improvised.

determined, the final apparatus should be applied as soon as possible.

Three can be recommended: a suspension appliance, Pierre Delbet's apparatus, and Alquier's appliance.

I consider the suspension appliance to be the best of these:

Because it allows of continuous extension in any position whatever, according to the requirements of each individual case.

Because it does not prevent careful supervision of the wounds and of the entire limb.

Because it allows of the maximum possible exposure

to the air or the sun, and does not closely confine the muscles and joints.

Because it greatly facilitates personal hygiene in that it is possible for the patient to move and lift himself with ease and without pain.

(1) *Suspension appliance with continuous extension.* —(i) *The Appliance.*—This is the Balkan apparatus

FIG. 116.—Frame for suspension splint.

still referred to as American, although its principle is apparently French. It comprises :

A frame of the type described on p. 224 and shown in fig. 38, or the overhead bar (fig. 115), which is very satisfactory in use.

A frame fitted as a sling with bands of linen. I

FIG. 117.—A very simple model of the metal splint necessary for the construction of a suspension hammock ; this model is the best.

have used many kinds of frames : one of deal with a support curved like the back of an arm-chair for the pelvic part (this is the simplest model, and easily

improvised anywhere); a metal frame constructed on the type of Blake's, the outer border extending from the anterior superior iliac spine to 2½ inches beyond the heel, and the inner border from the pubes to 2½ inches beyond the heel, 6 inches wide at the foot, and 14 inches wide at the groin (fig. 110); the frame used by Tuffier, the form of which is shown in fig 116; the double metal splint shown in fig. 117 and also in fig 105. All of these have given me the same good results, but the last of the models shown is certainly the most practical, on account of the two connecting arches, which can be used, the lower for fixing the foot, and the upper for drawing the appliance backwards, maintaining its position, and preventing slipping.

When possible, however, a *jointed splint* should be used, as shown in fig. 118. This allows of flexion of the leg on the thigh *; a screw joint and curved guides on each side make it possible for the leg to be placed in any degree of flexion desired.

The suspension sling is completed by strips of bandage; at the level of the wound this material is replaced by a double sterile towel, one enveloping the dressing, and the other acting as a sling. The four hooks are intended for suspension of the apparatus in the usual arrangement (fig. 115).

The weight necessary for counterpoising a thigh varies from 4 to 5 kilogrammes, according to the weight of the limb and the amount of friction in the pulleys.

(ii) *Continuous extension.*—I have always employed traction by bands of strapping, applied as in the classical type of extension (Tillaux). If this is to be well tolerated, the limb must first be shaved and washed with ether; the crural extremities of the two

* Soubbotitch recently described an ingenious and simple appliance facilitating treatment in the flexed position (*Académie de Médecine*, Oct. 24th, 1916). The original feature of his metal rest is a joint which allows automatic lengthening of the femoral inclined plane between the tuberosity of the ischium and the popliteal space, thus adapting itself to the increased length of the thigh in extension.

parallel bands must be divided into strips, which cross each other ; instead of using circular strips of strapping to fix the parallel bands in position, a spiral strip should be applied from the malleoli to above the knee.

If the pull is to be exerted with the limb flexed, the imbrication on the thigh should be very precise, and a few circular bands will be necessary for fixation ; the lowest of these should be sufficiently far from the

FIG. 118.—Jointed splint permitting treatment by flexion at the knee and hip joints. When the patient represented here was lying down, the thigh was flexed to 45° on the pelvis.

patella not to come in contact with it, as this is very painful. As the weight required for extension is much greater in flexion than in extension, traction may also be exerted through bands of strapping placed over a dressing surrounding the knee.

Certain patients do not tolerate traction well ; the bands take the skin off, and in a short time cannot be endured ; under these conditions, the Finochietto stirrup as employed by Chutro * appears very suitable

* Heitz Boyer has recently modified it by the addition of a flanged aluminium foot-piece and a transverse spring, which ensures a good position of the foot in flexion or extension on the leg under all circumstances (*Société de Chirurgie*, October 25th, 1916).

(see fig. 33), if the pull is to be exerted in extension. I have no personal experience of it.

(iii) *Choice of position for extension.*—This is decided by clinical examination

FIG. 119.—Double fracture of the thigh, seriously infected, treated at the front by simple drainage of the soft parts; radiograph on arrival under my care on the eighth day. My first idea was to amputate.

FIG. 120.—Radiograph one month later: complete subperiosteal esquillectomy. The periosteum is already very apparent; continuous extension has brought the lower fragments well downwards, but reduction is not, however, sufficient, as the upper fragment is projecting forwards.

and radiographs taken from both aspects. In a general way, traction with the limb flexed on the pelvis (30°)

FIG. 121.—Third radiograph, one month after the former. The limb has been placed in a suspension appliance, in an almost vertical position, at first in line with the trunk, then in abduction. The anterior displacement of the upper fragment was thus almost completely corrected, and the intermediate fragment carried outwards, but abduction has had an unfortunate effect on the upper fragment.

FIG. 122.—Fourth radiograph at the end of the fourth month, traction of 7 kilos having been applied, in line with the trunk, and with flexion to 45°, in a suspension appliance. The reduction is now very satisfactory.

in marked abduction (45° to 50°) is suitable in fractures of the upper part of the bone; in fractures of

the middle, traction with the knee extended, but with more or less pronounced flexion of the thigh on the pelvis (30° to 80°); in fractures of the lower part, traction with slight flexion of the thigh, and flexion of the leg to about 30°.

But there is an optimum position for each individual case; slight abduction is often necessary for fractures of the middle part of the bone, or slight flexion of the leg to counteract the backward rotation of the lower fragment; sometimes it is necessary to place the thigh almost at a right angle to the trunk. In a case, radiographs of which are reproduced (figs. 119, 120, 121, and 122), I was obliged to alter the position of the thigh several times to effect reduction: traction was first applied with the thigh flexed to 85° on the pelvis, in order to correct a forward projection of the upper fragment; then it was applied in adduction with the object of bringing the intermediate fragment into line; finally, the limb was brought straight again. The radiographs show the successive stages of this treatment and the result obtained. These successive and necessary stages would have been impossible with any ordinary appliance.

(iv) *Fitting the apparatus.*—When placing the limb in the splint, an assistant should make firm traction on the thigh and the leg, so that pain may be avoided and nothing may move in the region of the fracture, which is further supported by two hands beneath it. The splint is prepared beforehand and is slipped under the limb and passed as far upwards as possible so that it takes purchase from the pelvis: this is essential.

Traction is immediately made by the weight estimated to be necessary; a weight of 3 kilogrammes is used at first, and increased each day by 500 grammes, until 7 to 8 kilogrammes is being used: this extending force will generally effect axial reduction. If a double inclined plane is used, 4 kilogrammes is often sufficient.

The suspension cords are then fixed to the hooks,

and the counterpoising weight placed in position : this should be about 4 to 5 kilogrammes ; the weight must be sufficient to suspend the splint and the limb just off the bed, with the limb slightly flexed on the pelvis. If there is pain, the weight is increased and the position of the median pulley on the cord shifted until a painless equilibrium is obtained, and then the position of the traction pulley should be finally fixed. The steps of the procedure cannot be definitely described ; only one rule can be given : in proportion as the patient suffers, the position is bad. When the appliance is in good equilibrium, all movements of the limb as a whole are possible and not painful.

The sterilised sheets are then applied beneath the splint, and the whole apparatus is enveloped in a small covering of sterilised wool, in order to keep the limb warm. A small pad of cotton wool may also be placed between two layers of gauze and the foot covered with it.

As is always the case when the lower limb is immobilised, the mattress should be firm, and made resistant by slipping fracture boards beneath it : this is the classical procedure.

(v) *Care of the foot.*—The position of the foot should be examined every day in order to prevent the development of a troublesome pes equinus. The patient should be advised to practise frequent movements of flexion and extension, in order to avoid stiffness of the tibio-tarsal joint. For greater safety, if necessary, the foot should be kept at right angles by means of a flannel bandage fastened to the lower curved metal arch of the splint, or by means of a small pasteboard or aluminium foot-piece attached to the sole.

(vi) *Method of dressing.*—In fractures in which the operation has been performed at an early stage, and subsequently remains clinically aseptic, dressing at long intervals is an excellent thing. If the wounds suppurate, I expose them each day to the air, if not

to the sun. For this purpose, or at least for dressing, the counterpoise weight is pulled down in order to raise the limb higher above the bed, the slings of the splint corresponding to the wound are unfastened, the dressing is removed, and a sterile towel is immediately folded and placed beneath the thigh, with its edges folded over the metal frame of the splint. Dressing is usually very simple after esquillectomy. Figs.

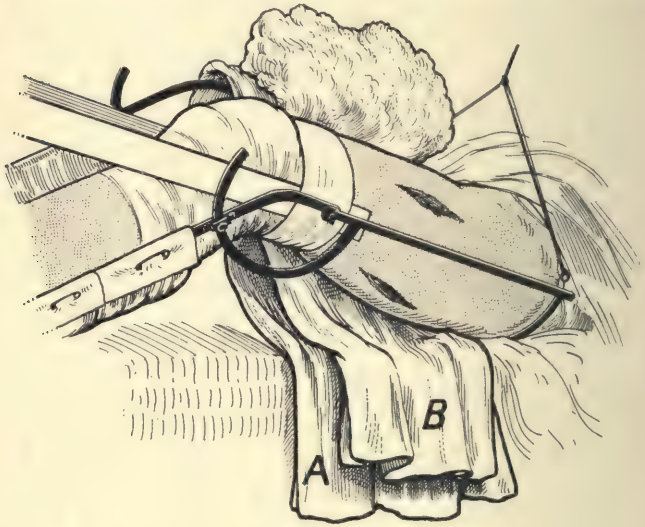

FIG. 123.

123, 124, and 125 are the best description of the suitable way of performing it.

(vii) *Possible complications.*—Apart from the trouble sometimes caused by the continuous extension bands, which offers much scope for the personal ingenuity of nurses, I know of only two possible complications—œdema of the leg and foot when traction is exerted with the knee flexed, and œdematous swelling of the lips of the wound.

Œdema of the leg is due to venous compression in the popliteal space; it can be made to disappear by altering the angle of flexion, removing the garter suspension band, or exerting the pull for some time with the knee extended.

An œdematous condition of the wound is the first sign of a slight deep infection, due sometimes to negligence in dressing, but almost always preliminary

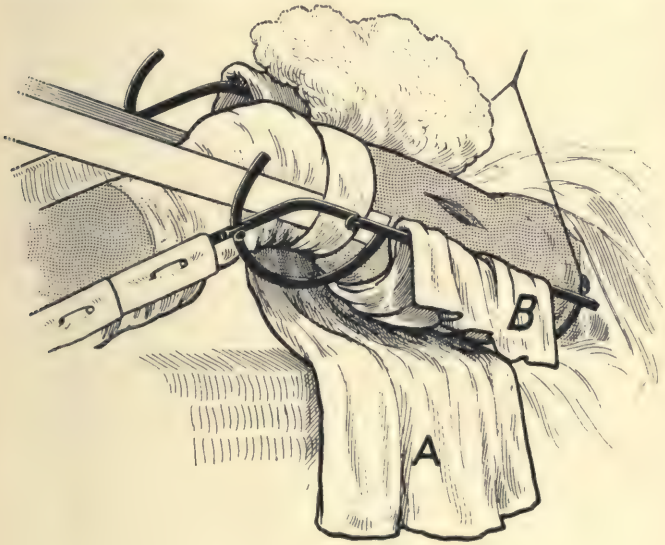

Fig. 124.

to the elimination of a sequestrum. Sometimes, but only after esquillectomy performed during the febrile state (it happens, in fact, towards the end of the second month), one of the extremities of the shaft becomes necrosed; a radiograph and exploration of the wound with forceps will detect the sequestrum and succeed easily in clearing up this slight complication. If necessary, the patient may be anæsthetised with

ethyl-chloride, and the cause of the trouble investigated in any suitable way.

(viii) *Duration of immobilisation.*—The progress of the fracture should be followed by radiographs. Unfortunately the suspension apparatus cannot be transferred with the patient to the X-ray room, but the extension may be easily removed, the suspension cords detached, and the limb carried in the splint.

As a rule, periosteal proliferation is visible in a good

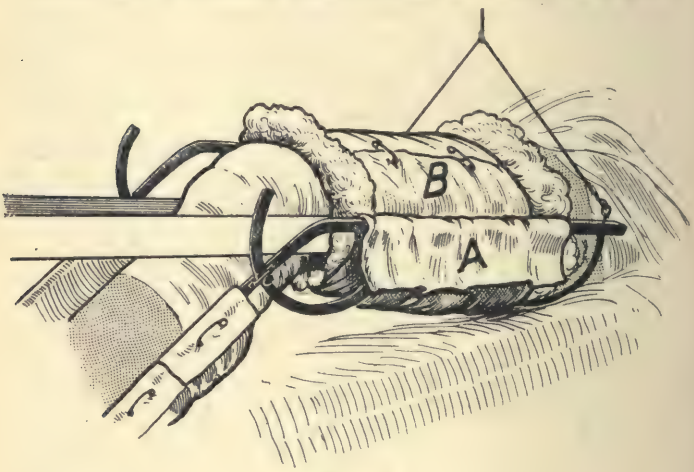

FIG. 125.

X-ray plate in the form of a more or less obvious shadow at the end of three weeks. At this stage the deep surface of the wound is granulating, and of a bright red colour, and is firm and regular to the touch.

At the end of six weeks the ossification is clearly outlined in the radiograph, usually on the side opposite to that of the surgical wound. Some patients are able, from this point onwards, to support the limb if it is lifted, but without always being able to raise the heel from the bed unaided. Subsequently the union becomes definite, and usually towards the end of the

second month, when healing is complete, the clinical impression is that of a firm callus.

In young subjects, continuous extension may be permanently discontinued at this point. In the case of older men, it is wise to continue it for a few weeks (until the hundredth day) in order to avoid secondary curvature.

Owing to the necessity for prolonged extension, it would seem advisable to use Delbet's appliance from the third month onwards.

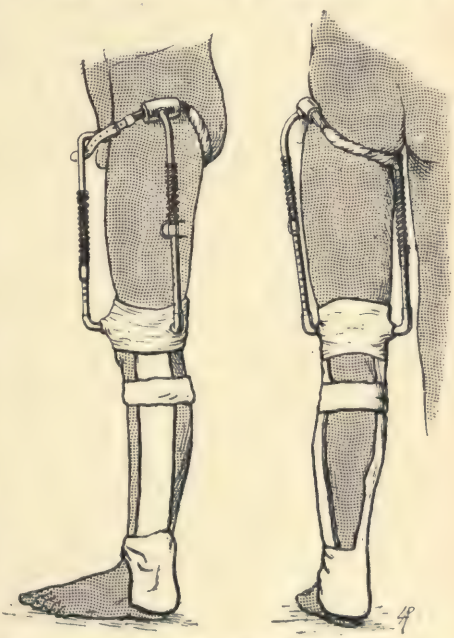

FIG. 126.—Pierre Delbet's apparatus.

(2) *Delbet's appliance.* — The object of this apparatus is to allow the patient to leave his bed and walk at an early stage. It consists of a metal pelvic ring specially curved which takes purchase against the ischium and the ischio-pubic ramus, and three spring extension shafts fixed below to a plaster collar moulded round the condyles. Of these three shafts, one is internal, one anterior, and the third, which is longer, ends in a hollow cylinder supported against the trochanter.

The accompanying fig. 126 explains the construction of the appliance.

The following are required for fixing it in position: an ordinary plaster bandage 2½ inches wide and 6 yards long, and a band consisting of twelve thicknesses of starched tarlatan 3 fingers in width and a yard long. This is split at each extremity along the median line and almost to its centre; in this way a four-tailed band is produced, which is intended to surround the lower part of the metal appliance on the thigh.

The appliance is fitted in the following stages:

Construction of a supra-condylar plaster ring, gripping the femoral condyles.

Padding of the pelvic ring.

Placing the pelvic ring in position, the supports, springs, and pins having been removed, but with the strap attached. It is placed on the inner side of the thigh, with its concavity facing upwards and outwards. The hand is slipped under the thigh, and, by means of the strap, brings the posterior part of the ring beneath the thigh, while the other hand applies it to the genito-crural fold.

Fitting of the strap, springs, and crutch-supports.

Application of the four-tailed band beneath the plaster collar.

Construction of a Delbet walking leg-appliance (see p. 288), which is fastened by means of a Scultet apparatus.*

When all is in position, time is allowed for the plaster to dry, and tension of the springs is brought into play, the internal spring being powerfully compressed, the external less, and the anterior very little.

During the following days the tension is modified so as to effect a progressive reduction, and when this has been obtained, the apparatus is fixed in

* Scultet's apparatus is a kind of many-tailed bandage, the ends of which are rolled round a cane on each side. The tails are brought together round the limb over the plaster in order to mould the latter to the contour of the limb and the apparatus is subsequently removed. For further particulars see Delbet, *Le Traitement des Fractures*. (Paris, 1916, p. 90.)—EDITOR.

position with split pins, and the patient allowed to get up.

The degree of tension of the springs and the condition of the skin in the genito-crural region require frequent attention.

At the end of about fifty days the leg-plaster may be removed. The rest of the appliance is kept on for at least two months.

This appliance has great advantages, which are recognised by all who have used it: it reduces well, allows the patient to get up at an early stage, and ensures a good ultimate result. It possesses the disadvantage of being difficult to apply well.

I believe that its use is particularly advisable during the period of convalescence, which it shortens considerably. I have only employed it in this late stage, and have no experience of its use in the earlier stages.

(3) *Alquier's appliance.*—By making use of certain parts of Delbet's appliance, Alquier has constructed an

Fig. 127.—Alquier's apparatus.

original apparatus, the excellent results of which I have seen at the hospital at Châlons, but which I have never actually employed. It has been described by Foisy, whose account is reproduced here:

It is a combination of a mechanical and a plaster apparatus. The mechanical part consists of five principal pieces: an upper collar, a pedestal-support, two lateral bars, and a traction appliance.

The upper collar is of metal, consisting of two parts, an internal ischio-pubic piece curved exactly as in Delbet's appliance, and another, external, jointed to the former behind, and also attached to it in front in the region of Poupart's ligament. A screw unites the two pieces firmly.

The semicircular pedestal-support has a large flat base, which acts as a support. A perforated transverse bar is fitted to the former, through which passes an extension screw.

The lateral bars are composed of four pieces, allowing adjustment according to the length of the limb and the width of the thigh. The inner bar is fixed at one end to the collar, and at the other to the pedestal, but the upper end of the outer bar slides in the collar, and ends in a crescentic pad which can be adjusted vertically and transversely, and takes purchase against the outer surface of the ilium; its lower end is fixed to the pedestal. The two lateral bars are supported about their middle by an extra pedestal-rest.

The traction appliance consists of a semicircular condylar collar ending in two wings sliding on the lateral bars, and a stirrup sliding in the same way.

The leg, knee, and popliteal space are padded, and a plaster apparatus is applied consisting of a collar moulded on the condyles, as in Delbet's appliance, and a plaster splinting extending from the lower part of the condylar collar to the base of the toes.

In fitting the apparatus, the upper collar is first placed in position,* and the limb is slung between the two lateral supports. When the upper collar has been secured, the external pad is fixed above the great trochanter, the collar is applied closely to the depression immediately above the condyles, and fixed there by means of a plaster bandage. Lastly, a stirrup is secured above the malleoli by means of another plaster bandage.

* Heitz Boyer has recently rendered the appliance more easily applicable, by making the external support movable.

When the plaster is dry, traction is gently and progressively applied so as to reduce the fracture in a few days.

6. The Treatment of cases first seen at a later stage or after previous Treatment—(*a*) *A case is progressing well after several days.*—After radiography and study of the displacement, the limb should be placed under continuous extension in a suspension apparatus. Early use of Delbet's appliance is also possible.

Operation is obviously unnecessary.

(*b*) *A case is seen with pronounced local sepsis.*—Whether the region has already been cleared or not, immediate sub-periosteal esquillectomy and drainage is indicated. After radiography, a radical operation is undertaken through an external incision: the soft parts are carefully cleaned with scissors, and a minute search is made for free splinters embedded in the muscles. When the region of the bone is reached, extensive esquillectomy is effected with the rugine. *I am more and more convinced that in the secondary period, sub-periosteal esquillectomy should be complete, bearing in mind the vital activity of the periosteum when irritated by the infection* (see figs. 24 and 25, p. 53). The medullary canal is scraped, gently and not excessively. Finally, the wound is packed with gauze moistened in hypertonic saline, and the limb is immediately placed in a suspension apparatus.

Fig. 128. — Bad comminuted fracture with numerous shell-fragments *in situ*.

The dressing should be renewed in forty-eight hours. After examination of the wound, and, if necessary,

completion of the mechanical cleaning by excision of any torn and gangrenous tissue, a fresh dressing moistened with saline is applied.

In five or six days the wound will generally be clean, the temperature normal, and the course of the case will be uneventful; dry aseptic dressings may then be used.

Elimination of a sequestrum from the ends of the

FIG. 129.

FIG. 130.

FIG. 131.

FIG. 129.—Radiograph on the fifteenth day after total subperiosteal esquillectomy (same case as fig. 128).

FIG. 130.—Radiograph at the end of four weeks, treatment being by continuous extension.

FIG. 131.—Radiograph at the end of five months: the wound healed in two months, and union occurred at approximately the same time. There is a shortening, measured several times, of $\frac{1}{2}$ inch. On the other hand, there is rather marked stiffness of the knee.

shaft may occur during the course of the second month. This is preceded by slight œdema of the edges of the wound, and a small amount of suppuration: a radiograph should be taken, and the sequestrum should be located and removed with forceps. This is usually easy, and is followed by immediate disappearance of the symp-

toms. The procedure materially shortens the duration of treatment, and prevents the formation of a sinus.

Continuous extension should be prolonged in proportion to the age of the patient and the extent of the original esquillectomy; walking should not be permitted until three months have elapsed. I have often seen union occur between the thirty-second and fortieth day, and one patient got up at the end of forty-five days, but this is not an example to be followed.

(*c*) *A case is seen after prolonged suppuration.*—In a case arriving after a month or more of treatment, with considerable suppuration and daily rise and fall of temperature, treatment is a difficult matter. Complete esquillectomy and drainage are no longer possible, since a considerable extent of the bone is diseased, and inopportune trauma would provoke an acute infection the gravity and results of which it is impossible to calculate.

Only what is strictly necessary should therefore be carried out—freer drainage of the soft parts, removal of easily accessible sequestra without interfering with any that are adherent, the opening of abscesses, and a patient watch for developments. The temperature will often become normal and the general condition improve as a result of such simple interference, but an operation on the bone itself will always ultimately be necessary. Previous to this, and after all minor interventions, a warm moist dressing is very effective in reducing the phenomena of sepsis.

If the situation has not distinctly improved after some days, amputation must sometimes be considered. Too frequently days pass in hesitation and delay, and the amputation is performed too late to combat the effects of chronic septicæmia. In these cases I usually perform a circular amputation, leaving a flap of skin of greater length than is necessary, which is well retracted; the muscles are cut in one transverse sweep, and the flap is left turned back on the skin. This

gives complete exposure of the area and is very favourable for the immediate arrest of septic conditions.

Sometimes high temperature persists after the amputation, and the situation is then one of anxiety : under such circumstances I have found it well to employ a large warm bath (102° F.), in which the patient remains for two hours. After the bath, I have seen a regular fall of temperature by lysis, and great improvement in the general condition, the patient being very soon out of danger.

(*d*) *A case is seen with a sinus.*—There is no region where a bone sinus is more difficult to cure, when esquillectomy has not been performed. Cases certainly occur, in which the sinus is simply evidence of slight superficial osteitis, but more often it leads to a septic cavity or to a deeply imprisoned sequestrum. The lardaceous and rigid muscles form a troublesome obstacle to any attempt at exposing the bone, and prevent exposure of the region and free drainage.

After a precise conception of the situation and extent of the lesions has been formed from a radiograph, there should be no fear of too comprehensive an operation, or hesitation in deliberately sacrificing sclerosed muscular tissue which can never function : it is useless, and extremely inconvenient.

(i) *If there is an osseous cavity*, one side of it must be removed, and the edges bevelled, that is to say, it must be thoroughly exposed as far as this is possible : this is an essential condition for cure. When the cavity has been well disinfected by exposure to the air, by hot air, and particularly by the sun, it may be plugged with Mosetig's iodoform mixture, or with bismuth in the form of Beck's paste, which will perceptibly shorten the duration of treatment. I do not mean that secondary suture should be done after the plugging, although this is perhaps often possible, but it seems scarcely wise without bacteriological examination ; the only object of the plugging is to facilitate oblitera-

tion of the cavity with newly-formed tissue. After plugging, I leave the wound open to the air during the day; during the night, the dressing is a simple sheet of gauze for purposes of protection. It has seemed to me that healing is markedly accelerated by this procedure.

(ii) *If a sequestrum is present*, it should be cut down upon, however large an incision may be necessary for the purpose.

Here, more than anywhere else, random scraping should be avoided.

(*e*) *When union has occurred with marked shortening.*—With a shortening of less than 1¼ in. there is virtually no lameness. With a shortening of 2½ in. the patient walks lame, but is not seriously inconvenienced; it is enough to wear a thick sole. As a matter of fact, shortening cannot be referred to as "marked," and be said to necessitate a special boot, unless the difference in length between the limbs exceeds 2½ in.; but it seems to me useless, in the actual state of affairs, to attempt to modify a shortening of less than 4 in.

Marked shortening is almost always due to faulty reduction, vicious union, lateral angulation, or overriding. The most typical case is that of an externally bowed callus in a fracture of upper part of the shaft.

In these cases, correction of the deformity and lengthening of the limb by osteotomy may sometimes be considered, but for this the following conditions are necessary:

(i) The fracture must not be suppurating, the callus not osteomyelitic, there must be no sequestrum, sinus, or infected central cavity; otherwise intervention may be followed by fatal septicæmia.

(ii) The callus must not be too mis-shapen or voluminous; otherwise the operation will be practically impossible.

When these two conditions do not definitely contra-

indicate osteotomy, a marked improvement in the condition of certain cases may be obtained.

Oblique osteotomy of the callus should be performed, with a minimum of trauma ; for this purpose a Gigli saw is sometimes preferable to the osteotome. The wound should be left without sutures, and straightening effected by continuous extension in a suitable position, as for a recent fracture ; immediate straightening and reduction with metallic osteosynthesis is not advisable.

In a fracture of the upper third of the thigh, with

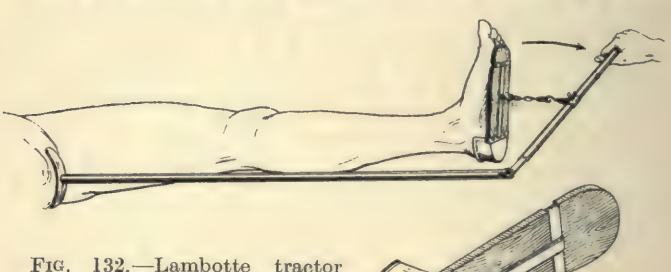

FIG. 132.—Lambotte tractor simplified: this was constructed by a locksmith according to Cotte's instructions.

marked deviation of the upper fragment in abduction, I obtained a perfect reduction in this way, with recovery of 2 inches in length.

(*f*) *A case is seen with a pseudarthrosis.*—This is a rare occurrence ; up to the present time, I have only seen pseudarthrosis of the femur in the sub-trochanteric region, and as a result of non-reduction.

Osteosynthesis by a Lambotte plate is definitely indicated in such cases.

(i) In sub-trochanteric fractures the condition of the hip-joint should first be investigated, and an attempt made to move the fragment of the femur by separating the insertions of the pelvi-trochanteric and buttock muscles with a rugine.

If the joint is immovable the shaft may simply be fixed by a plate to the sub-trochanteric border of the upper fragment, which is trimmed for this purpose. This causes marked shortening (about 2 in.), but the result appears satisfactory. I have obtained cure of a pseudarthrosis and a satisfactory recovery of function without difficulty by this operation ; the plate remains in position (observation eight months old).

(ii) In fractures of the shaft a considerable extent of the femur should be resected, until, in fact, healthy bone is reached, as in pseudarthrosis of the humerus.

Reduction is effected by a lever of the Lambotte type. I have used the simplified model illustrated above, which was improvised by a locksmith according to Cotte's instructions (fig. 132).

III. Supra-condylar Fractures

1. Anatomical Features.—The direction of the fracture is usually oblique from behind forwards and rather irregular, with small splinters, particularly posteriorly ; its general appearance resembles that of supracondylar fractures in civil practice. At first the damage often appears not to be very great, but in reality *there are almost always several fissures radiating into the joint ;* these fissures sometimes end at the cartilage, but usually the latter is split, and the fracture of the shaft becomes an articular fracture. There is no external sign of this penetration of the epiphysis ; there is often no hemarthrosis, and the fissure is invisible in a radiograph, whatever its position, whether intercondylar or transcondylar.

Apart from these cases, a T-shaped and definitely intra-articular fracture is of common occurrence.

There is often considerable injury to the soft parts, which is increased by the rotation of the fragments ; laceration of the tissues beneath the quadriceps frequently occurs.

The point of the lower fragment sometimes comes into contact with the popliteal vessels, contusing or lacerating them.

Nerves are usually uninjured.

2. Physiological Features.—Two different forces come into play to produce the displacement, which is usually very marked: by the action of the quadriceps, the upper fragment is displaced forwards, sometimes also slightly outwards or inwards, piercing the tendon of the quadriceps, and projecting beneath the skin or into the wound.

Fig. 133.—Supra-condylar fracture: the radiograph does not show a fissure which passes down between the two condyles as far as the articular cartilage.

The lower fragment is pulled backwards by the gastrocnemius and soleus, causing a pronounced rotation towards the popliteal space, and bringing the upper extremity of the epiphyseal fragment into contact with the vessels.

3. Course.—Since there is little comminution, this fracture may prove mild, provided that there are no transepiphyseal fissures, no perforation of the joint, no vascular lesion, and no subsequent sepsis. I have seen them progress without difficulty (after early disinfection), cure aseptically and without complications, but with great limitation of movements. In one of these cases a late orthopædic resection was necessary and gave an excellent result.

Usually, however, the position is less favourable; the epiphysis is split and the cartilage fissured. If the

wound is not disinfected immediately, if the fracture suppurates, infection spreads along the fissure, and after a few days of apparently favourable progress, serious suppurative arthritis suddenly develops, and immediate amputation is necessary. During the last few months I have been obliged to amputate in three cases evacuated from the front with infected supra-condylar fracture. In all three cases amputation of the thigh was necessary during the course of the third week, shortly after their transport, and in each of the three cases infection of the joint had occurred through a radiating fissured transcondylar fracture; there were very marked lesions of the cancellous tissue of the epiphysis.

Supra-condylar fracture is therefore a grave injury. When it is added that reduction of the displacement is always difficult, it will be understood why the prognosis should always be very cautious.

FIG. 134.—Cure with ankylosis of a supra-condylar fracture from a shell-fragment, on which no operation was performed. A small oozing sinus had persisted for a year past: ankylosis with flexion. An orthopædic resection was performed, and gave an excellent result.

4. INDICATIONS FOR EARLY TREATMENT.—The frequent occurrence of fissures of the condyles which are invisible in a radiograph necessitates as careful a preventive disinfection as possible, without which arthritis is almost inevitable.

This disinfection should include sub-periosteal removal of all splinters projected into the popliteal space,

and careful and gentle curetting of the epiphyseal cancellous tissue.

If this operation is performed at an early stage, no complication of the condylar lesion occurs, even when a penetrating fissure exists. In the case of associated injury to the synovial membrane (which is common), this should be cleaned, the lacerated borders of the synovial membrane excised and the edges sutured, after which the fracture itself is treated.

If there is laceration of the vessels they are ligatured, if necessary, without abandoning conservative treatment, unless gangrene is threatening or evident.

Sometimes, however, complete exploration will lead to the discovery of lesions such that immediate amputation will appear advisable. Amputation should be performed if injury to the bone is too extensive (more than 4 inches of the femur), if the lesions of soft parts (vessels and nerves) are such as to afford little hope for the future, if, together with grave lesions, there are already signs of articular infection, and, finally, if there is gangrene of the foot.

In theory, it seems that amputation is rarely necessary; in practice it frequently is, and after these early amputations at the front, subsequent investigation of the lesions almost invariably justifies the serious decision made.

5. Technique.—In the absence of special indications furnished by the position of the wounds, the region of the fracture is approached by a lateral external incision parallel to the biceps, but slightly anterior to it, and ending below at the condylar prominence. Unless an internal incision is necessary to reach splinters that have been projected inwards, this single incision will suffice, which is an advantage from the point of view of the vessels and nerves. An incision in the popliteal space is bad, and should never be made: drainage in contact with the popliteal artery and branches of the sciatic nerve would be particularly misplaced.

As a rule, the operation is easy.

The same cannot be said of the immobilisation of these fractures. The backward rotation of the lower fragment necessitates immobilisation with the leg flexed, and the forward projection of the upper fragment necessitates flexion of the thigh on the pelvis.

Any form of immobilisation with continuous extension which does not take these two desiderata into account should therefore only be temporary.

As a provisional arrangement, at the front, the plaster trough is a solution of mediocre value, but acceptable for the time being ; as soon as possible, the double inclined plane should be resorted to, which may easily be improvised with two boards of equal dimensions, united by two hinges, and fixed by a rack.

When a choice is possible, Hey-Groves's appliance (described on p. 247) should be used, and is excellent from this point of view ; the suspension appliance with a jointed frame (as illustrated on p. 253, fig. 118) is good. I have treated a high supra-condylar fracture by means of this appliance, and obtained an excellent reduction. I refer the reader to details given in connection with the above-mentioned splint.

6. Treatment of cases seen at a later stage or after previous Treatment.—(*a*) *A case is seen progressing well.*—This is unusual, and up to the present I have never admitted from the front a supra-condylar fracture, due to a shell-fragment, in a good condition. Immobilisation should be effected, as has been stated above, on a double inclined plane. Continuous extension is not always necessary, but if it should be, it is carried out by exerting a strong downward pull on the condyles, in an attempt to rotate the lower fragment back into position.

Immobilisation should be continued for three or four months. Union in these epiphyseal fractures is often very slow. Considerable stiffness of the knee must be expected.

(*b*) *A case is seen in a septic condition.*—Three types of condition are possible:

(i) If it is a fracture which has not been disinfected, immediate esquillectomy is necessary. The two pointed ends are smoothed off with a Gigli saw. Any radiating fissure should be located and cleaned with a curette, the cancellous tissue in its vicinity being scraped away. If necessary, hemarthrosis of the knee is relieved by puncture.

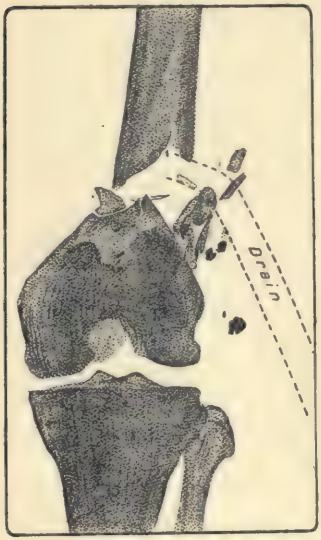

FIG. 135.—Supra-condylar fracture treated at the front by drainage of the soft parts and intermittent irrigation. Evacuation on the fifteenth day; condition apparently good. Four days later, suppurative arthritis and serious general condition; amputation of the thigh. An infected fissure, which the radiograph does not show, passed through the outer condyle as far as the cartilage, which was split.

If a penetrating fissure exists, resection of the knee should be performed at once, including removal of a thin layer from the tibia.

If the infection is not rapidly checked, the attempt at preservation should not be continued too long, but amputation should be performed without delay, even if the line of fracture and consequent shape of the upper fragment are favourable for resection of the knee; these fractures are very serious when preventive disinfection has failed.

(ii) If the fracture is seriously infected, with evident injury to the joint, which is also already infected, resection is sometimes possible, but more often immediate amputation is necessary. A few isolated

fortunate cases, which will never be anything but exceptions, cannot blind us to the fact that deaths have been caused by undue delay in amputating in these fractures.

(iii) If the foot is gangrenous, which indicates a vascular lesion, amputation is also necessary.

(*c*) *A case is seen with vicious union.*—There are vicious unions which should be recognised as unsuitable for intervention—viz. those which are still infected, or are accompanied by a large inflamed callus. On the other hand, effective intervention is possible by orthopædic resection, in simple vicious union, due to absence of reduction, with a stiffness of the joint practically amounting to ankylosis: very limited orthopædic resection of the tibia has enabled me to obtain a firm knee in the extended position. The same is the case when the shaft of the bone becomes impacted into the condyles in a position of angular deformity. In a case suffering from ankylosis with flexion of this kind, resection gave me a perfect result (fig. 134).

(*d*) *A case is seen with a pseudarthrosis.*—I have never seen an example of this, but it is a possibility, pseudarthrosis being caused by lack of reduction and muscular interposition. Operation on the region of the fracture and introduction of a Lambotte plate on the outer side seem to me the best procedures.

(*e*) *A case is seen with a sinus.*—All sinuses which I have seen co-existed with ankylosis of the knee, and curetting of the cancellous tissue after this has been widely exposed by a transverse incision easily produced a satisfactory result. The conditions may, however, be different: notably, multiple sinuses may occur, due to different causes—cancellous osteitis below, a sequestrum from the shaft above and behind. In these cases the operation should consist of several stages, each lesion being treated separately according to the nature of its cause.

CHAPTER VII

FRACTURES OF THE LEG

THE following groups may be distinguished :

Fractures of both bones about the middle, and in the lower third (supra-malleolar).

Fractures of the tibia alone.

Fractures of the fibula alone.

I. Fracture of Both Bones of the Leg

In practice, fracture of the upper epiphyses of the bones of the leg is only seen as an injury to the joint, which should be treated by resection. Fractures of the malleoli are also almost always fractures into the joint. I shall only deal here with definitely diaphyseal and supra-malleolar fractures.

A. Fractures of both Shafts.—This term includes any fracture between the tuberosity of the tibia and the lower third of both bones, 2 in. from the malleolus.

1. ANATOMICAL FEATURES.—The most usual type of fracture has large diamond-shaped splinters in the tibia, and comminution of the fibula. Fracture of the tibia of the large short-splinter type, with transverse fracture of the fibula, also occurs, and still more common is comminution of both bones.

The higher up the fracture (*i.e.* the nearer to the upper tibial epiphysis) the more frequent is the comminuted type. On the other hand, the lower down the position of the fracture, the more often does the large-splintered type occur.

Lesions of the vessels and nerves are very frequent.

2. PHYSIOLOGICAL FEATURES.—The displacement is always more marked in the tibia than in the fibula. There are two opposing muscular forces—that of the quadriceps femoris, which pulls the upper fragment forwards, and that of the calf muscles, which tries to displace the lower fragment backwards. The result is a frequent angular displacement with its apex backwards; the leg appears to form a curve with a marked anterior concavity. At the same time there is almost always lateral displacement. Lastly, the weight of the foot usually exerts a lateral pull on the lower fragment, producing a certain degree of rotation on the long axis of the bone, *i.e.* internal or external displacement by torsion. In spite of this, the displacement is never very great.

FIG. 136.—Large-splintered fracture of the tibia (common type).

FIG. 137.—Postero-lateral angulation in a fracture of the leg.

3. COURSE.—When left alone, a fracture of both bones is often complicated by gas gangrene, since there is extensive muscular injury beneath resistant fasciæ, and often associated vascular lesions.

In cases which escape these immediate complications, the development of serious septic acute osteo-

myelitis of the fractured area is virtually constant and leads to the formation of sequestra, profuse suppuration, pus tracking down the calf, destruction of the fasciæ, and secondary hæmorrhage.

After drainage, which causes permanent rigid and contractile cicatrices in the muscles, one of two conditions usually develops : either a redundant inflamed callus is formed, enclosing an empty medullary cavity (see p. 30, figs. 10 and 11), or the dull white extremities of the tibial fragments undergoing necrosis are seen in the wound, and after their elimination, the devitalised ends of the shaft are left, rarefied and without any sign of union, and decidedly unsuited for plating.

Of these conditions the former is the more common. Owing to the suppuration, it is difficult to ensure rigid immobilisation, and a frequent result is the formation of a faulty callus with posterior angulation, so that the leg forms a bold curve with its concavity forward, or with outward or inward displacement by torsion of the foot, and almost always a degree of pes equinus, which soon becomes difficult to correct.

In short, the cure of septic fractures of the leg is too often only very moderately satisfactory : in these, more than in fractures in any other region, anatomical preservation is by no means identical with preservation of function.

4. Indications for early Treatment.—A prophylactic clearing operation should be done as early as possible : this is a *sine quâ non* if good functional use is to be hoped for.

There are cases, however, in which this immediate operative disinfection is only a prelude to immediate amputation.

Amputation should be performed at once when destruction of the bone is too extensive to afford any hope of adequate anatomical repair. Judgment on this point is not an easy matter, and the decision in such a case

depends largely on the individual. In general, it is better to err in the direction of too frequent attempts to preserve the limb; sub-periosteal esquillectomy allows one to go very far in this direction without danger.

It would seem, however, that when the bone-injury involves more than half the length of the leg (not, of course, including fissures, but merely the splintered region), immediate amputation is preferable.

Similarly, when the injuries to soft parts, muscles, vessels, and nerves, are such as to afford no hope of satisfactory functional recovery, it is better to amputate at once, since preservation would cause the patient to run considerable risks for an illusory benefit.

Finally, the seriousness of the general condition may sometimes necessitate an early amputation, when an extensive area has been comminuted. But I regard this indication as extremely rare; the necessity only exists when it is of importance to demand a minimum of effort from the system (*e.g.* when the patient is almost bloodless, and in danger of grave infection). Even in such a condition as this, a more appropriate course than amputation would probably be transfusion, followed by esquillectomy later on.

In all other cases, early sub-periosteal esquillectomy should be performed at once, for the two reasons already mentioned—to prevent complications, and to facilitate union.

5. Technique.—(*a*) *The operation.*—This is performed by means of two incisions, one along the crest of the tibia, and the other over the fibula, the existing wounds being used if convenient; there should be no hesitation in making fresh incisions at the seat of election if the entry and exit wounds are inconveniently situated.

The tibial incision should be made on the aspect of the bone internal to the crest: separation of the periosteum with the rugine is begun at once and as

much of this as possible is preserved; the region of the fracture should be carefully cleaned, and if necessary, sound bone cut away from the antero-internal surface of the tibia in order to expose its posterior aspect. Esquillectomy is then carried out in the fibula, but this need not be so extensive, as the fragments over-ride without any trouble, when the difference between the gaps in the two bones is not too great. Unless this precaution be taken, the orthopædic result is not satisfactory; mechanical forces do not act normally on the fragments, the progress of bone formation in the two bones is not correctly correlated, and there is danger of faulty union at some point, if not of pseudarthrosis. The shortening of the fibula should therefore be systematically ensured.

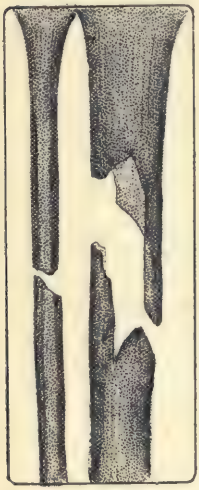

FIG. 138.—Radiograph after total sub-periosteal esquillectomy. The leg is in a continous extension plaster apparatus, of the type represented in fig. 138 (cf. figs. 136 and 137).

At the conclusion of the operation, it is absolutely useless to make an incision through the muscles of the calf, for purposes of drainage; the sole effect of this is to leave dense scar-tissue in them.

(*b*) *Immobilisation.—The essential point is that this should ensure preservation of the normal axis of the lower limb*, since any deviation from the normal static line has infinitely more serious functional results than has shortening. During the whole period of immobilisation, therefore, any angular deviation must be accurately corrected and every effort must be made to re-establish the long axis of the tibia.

During the first few days I employ a metal splint, pending the first dressing. The latter, if conditions

are normal, is postponed until the sixth or eighth day, when I finally immobilise the limb by one of the three following procedures :

A simple posterior plaster trough suffices in many cases, where esquillectomy has effected a complete reduction, and there is no sepsis to necessitate frequent dressing (Vol. I, fig. 70).

In a case of this kind, good union was observed to have occurred in thirty-seven days, when the third dressing was applied.

More often, however, *a continuous extension appliance* is necessary.

Excellent permanent traction can be applied by the use of plaster, in the following way :

Two sets of curtain-rods are prepared, one rod sliding on the other in each case ; these are cut so that, allowing for a fair amount of extension, the two rods fitted one over the other are about equal in length to the leg (fig. 139). A well-modelled plaster boot is then made, not fitting too tightly, and in the centre of the sole is incorporated a loop of bandage, or a metal hook, to act as a traction ring. The knee is next enclosed in plaster, which extends down immediately below the anterior tuberosity of the tibia. The two parts of the plaster are connected on each side by means of a pair of the telescopic shafts, which are held in position by an assistant three fingers' breadth away from each side of the leg. Each shaft is fixed firmly to the plaster at one end (fig. 139) by means of a plaster band rolled as is indicated in figs. 140 and 141. The assistant keeps the telescopic traction shafts exactly parallel to the axis of the leg until the plaster is dry, this being done first on one side and then on the other. A small splint should be incorporated in the dressing behind during the first few days to support the calf.

I have treated a considerable number of serious fractures with this improvised appliance, and the

results have been excellent. It is only necessary to be extremely careful not to immobilise the bones in a

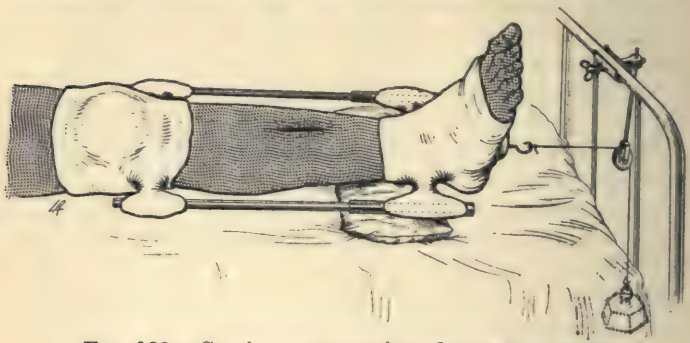

FIG. 139.—Continuous extension plaster apparatus.

bent position, and to push the upper fragment forwards before fixing the metal shafts.

FIG. 140.—Method of fixing the sliding rods: the band passes from the plaster to the outer shaft, and is then wound in a spiral around the original loop.

Further simplification is sometimes possible, nothing being applied to the upper part of the leg but a plaster

collar identical with that in Delbet's walking appliance :

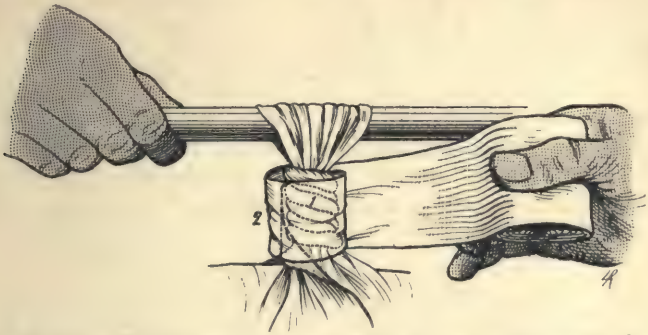

FIG. 141.—Finally, regular circular turns are made round the plaster bridge which has thus been made.

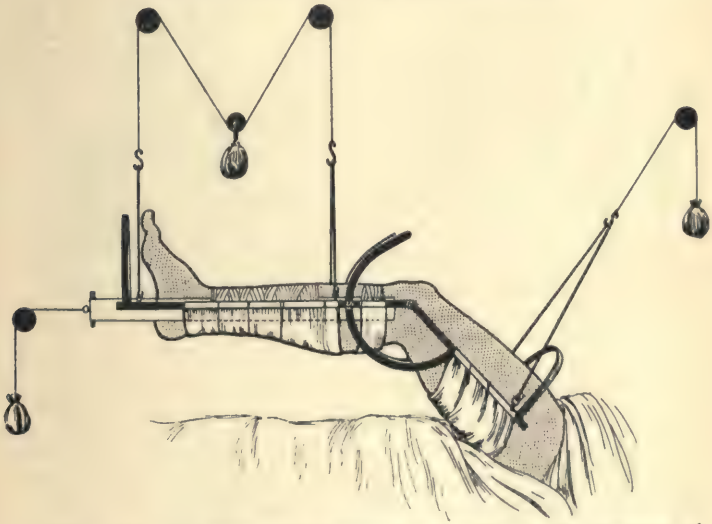

FIG. 142.—Diagram of a suspension appliance for fracture of the leg : the three suspension pulleys are attached to a horizontal bar of the ordinary type.

the knee remains free, and a certain amount of flexion is possible. As a matter of fact, it is preferable not to

employ this form of the appliance until the fracture is well on the way to unite. The telescoping curtain-rods may be replaced by a double spring shaft, comparable to those in Delbet's appliance (fig. 37, p. 100).

But in bad fractures with extensive injuries to the soft parts, these appliances cannot be used; in these cases *the suspension appliance* is the most suitable.

An appliance may be used which is identical with those described on p. 252 for fracture of the thigh, and

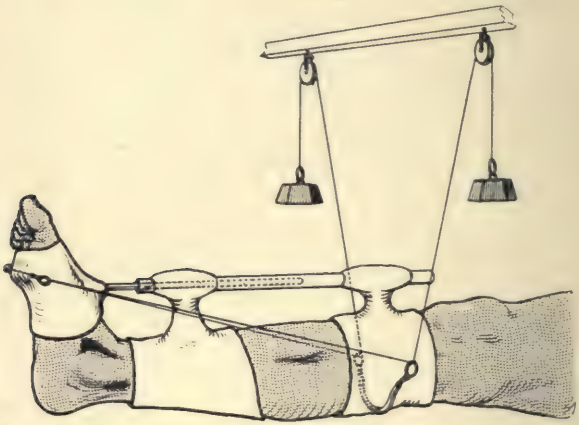

FIG. 143.—Continuous extension plaster for a fracture which is uniting, but with associated pes equinus: correction of the latter slow, owing to previous articular suppuration.

continuous traction may be exerted, the entire lower limb being in extension. It is better, however, to use a jointed frame, traction being exerted with the knee flexed. The practical details given in connection with supra-condylar fractures of the femur render further description of the appliance unnecessary. Its construction is shown in fig. 142. The counterpoise should be from 4 to 5 kilogrammes, and the extension, from a strapping stirrup, 5 to 6 kilogrammes.

(*c*) *Care of the foot.*—It is absolutely necessary to

watch the position of the foot. Bad positions of the foot too often spoil the functional result after perfect union of the fracture. Moreover, a number of these abnormal positions are due to reflex contractures which are difficult to cure. Continual attention should be given to the foot, in order to prevent the development of equinus, varus, or valgus. These details should receive consideration early in the treatment,

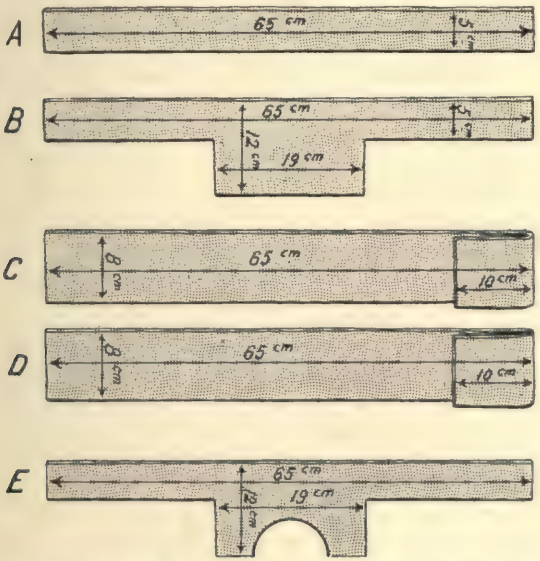

FIG. 144.—(A) Tibial piece. (B) Malleolar piece with heel-covering. (C, D) Lateral supports, 4 inches being folded back at the lower extremity. (E) Malleolar piece with heel piece.

and not towards the end. If the deformity already exists but has not developed too far, the normal position of the foot can be restored, either by means of a spring sole, or by an arrangement such as that shown in fig. 143.

(*d*) *Apparatus for convalescence.*—As soon as the size of the wounds is reduced, and union has begun,

it is an excellent practice to fit Delbet's walking appliance. This is usually permissible about forty days after the operation when there is no longer any need for continuous extension. The Scultet apparatus, which Delbet considers necessary, is not really called for : it may perhaps be more convenient, but I do not use it. To construct an appliance for walking, four tarlatan slips of the dimensions indicated in fig. 144 are prepared, and a fairly thin plaster paste, intended not to set too quickly. The slips and circular pieces are soaked in the liquid paste, spread on a table, smoothed, sprinkled with dry plaster, and placed flat on the leg. The malleolar ring is first applied, in such a way that the heel-cover does not extend below the heel. The circular tibial piece is similarly applied ; the upper border of this should coincide with, but not pass above, the anterior tuberosity of the tibia. The two lateral supports are immediately applied, care being taken not to encroach on the knee above, and to reach the border of the foot below, without passing beyond it. The upper collar is then arranged circularly around the leg and the two ends of the heel-piece are made to cross anteriorly above the instep, which should remain free. Nothing now remains but to mould the whole to the limb with an ordinary bandage, being careful to keep the foot exactly at a right angle, while moulding the heel-covering on the malleoli.

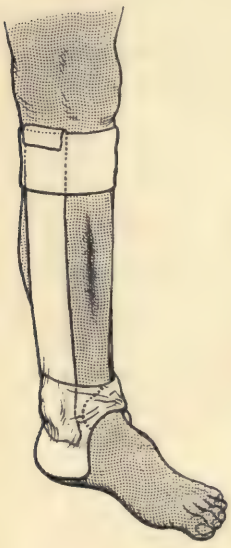

Fig. 145. — Delbet's walking appliance for fracture of the leg.

6. THE TREATMENT OF CASES SEEN AT A LATER STAGE OR AFTER PREVIOUS TREATMENT.—(*a*) *A case is seen doing well after several days.*—The wounds are insignificant, and the fracture is apparently going

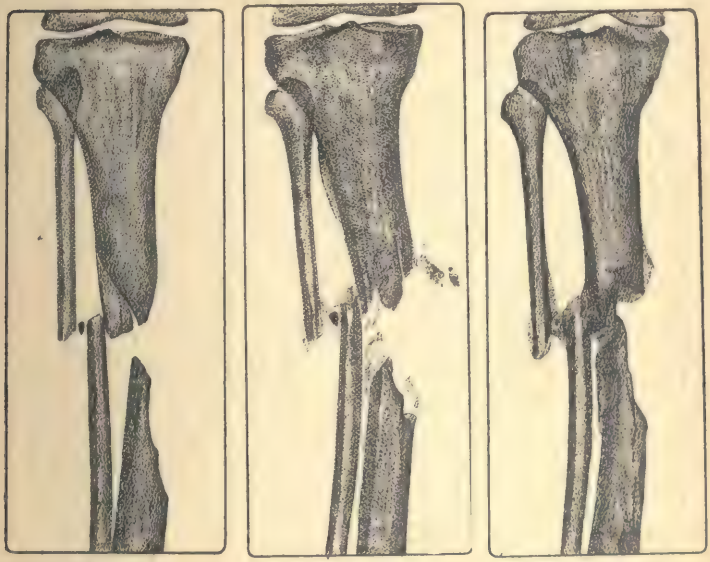

FIG. 146 FIG. 147. FIG. 148.

FIG. 146.—Severe fracture of both bones of the leg caused by a shell-fragment; sub-periosteal esquillectomy on the fourth day, followed by removal on the eleventh of a splinter that had been overlooked; radiograph on the fourteenth day.

FIG. 147.—Radiograph two months later.

FIG. 148.—Radiograph at the end of eight months. Union took four months, and was effected in a continuous extension plaster of the type represented in fig. 139. In spite of the tibio-fibular synostosis, the longitudinal axis of the bone is preserved; the result, from the point of view of function and equilibrium, is good. Musculature good. No sinus. Shortening of half an inch.

on as if it were caused by a bullet with punctiform wounds. It is necessary and sufficient to apply continuous extension for three or four weeks, and then to fit a walking appliance.

(*b*) *A case is found to be infected.*—The wound dates from some days previously, the leg is swollen, and there is suppuration. Complete sub-periosteal esquillectomy of both bones should be performed at once, care being taken to reduce the fibula to the same length as the tibia. Abscesses should be opened, but, except when definitely necessary, no posterior counter-incision for drainage is made, as this is useless. Immobilisation in plaster, with continuous extension, or in suspension, is immediately effected.

Under these conditions, if the case is carefully dressed and the position of the fragments continually re-examined, marvellous results will be obtained : very grave fractures will be cured without leaving any effects, and function will be recovered practically entirely (figs. 135, 136, 137, 145).

The position of the foot must be watched carefully in these cases : it will sometimes be necessary to contend with pes equinus ; in a complex case, in which I was obliged to perform arthrotomy of the ankle during treatment of a serious fracture, I used the arrangement indicated in fig. 139 to counteract pes equinus and to restore the foot to its normal position.

(*c*) *A case is seen at a late stage, seriously infected.*—The first month has passed, the periosteum has already reacted, and the outlines of a callus have been formed, but the wound is suppurating profusely, and sequestra are beginning to be eliminated. At this stage, esquillectomy is no longer possible ; the treatment will be merely drainage of the soft parts and removal of sequestra that require to come away. Intervention, if it is not to be dangerous, must be delayed until the osteomyelitis has been reduced to some extent.

If the lesions are very extensive, if the general condition becomes worse, if the temperature remains high after adequate drainage, and particularly if the shortening, due to elimination of sequestra, is marked (3 to

4 in.), and there are serious associated muscular and nervous lesions, it will sometimes be necessary to decide on amputation. Late secondary amputation has two indications which are very real, but difficult to express : it should be considered (1) when the general condition does not justify waiting too long for slow and probably poor anatomical repair, and (2) when the local conditions afford no hope of sufficient functional recovery.

(*d*) *A case is seen with a fistulous callus.*—In general the tibia is concerned, and there is either an osteomyelitic central cavity, with or without sequestra, or the bone is thickened by a condensing osteitis, which keeps up persistent ulceration of the skin.

In the former case, after careful separation of the periosteum, the wall of the cavity must be cut away and smoothed, exposing the medullary canal, in order that the cavity may be disinfected by exposure to the air, and ultimately filled in.

In the latter case, the hypertrophic bone must be gouged away, and the bone cut down, until the medullary canal, or what remains of it, is encountered, not by hollowing out a narrow groove, but by chiselling away the bone over a large area : there is no danger of carrying this too far.

Sinuses and osteitic ulceration may always be cured successfully in this way.

(*e*) *A case is seen with a pseudarthrosis.*—Usually pseudarthrosis only occurs in the tibia ; it is a more or less compact fibrous pseudarthrosis with bony union in the fibula. It is most common in the upper third of the bone at the junction of the epiphysis and shaft. Lower down, if union fails, it generally does so in both bones.

Before undertaking any treatment, the region must be disinfected if any sign of infection remains, sinuses must be cleaned, and sequestra removed ; then the area is widely exposed, without waiting for cutaneous

healing, the fibrous tissue between the two fragments is excised, and the extremities of the shaft are resected on each side until apparently healthy tissue is encountered. When two healthy surfaces of bone have been thus obtained, sufficient of the fibula is resected sub-periosteally to permit apposition, and the tibia

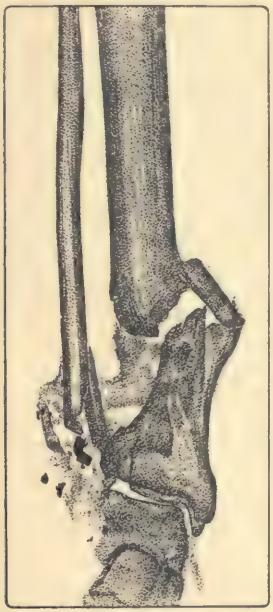

FIG. 149.—Vicious callus with multiple sinuses a year old.

FIG. 150.—Forcible reduction with osteosynthesis : uneventful recovery.

is fixed by one or two Lambotte plates. The wounds are left open, without sutures, and rigorous immobilisation is effected with plaster.

By this method I have brought about union without difficulty in the few cases of pseudarthrosis of the leg on which I have operated.

Bone-grafting is not advisable at this stage : or-

ganisms are latent in the tissues and no reliance can be placed on the result. I have never performed the operation, but at medical boards I have seen numerous failures, of which one hears nothing.

Lastly, there are pseudarthroses which require amputation. It must be remembered that the leg exists to carry the weight of the body in walking. If the pseudarthrosis is incurable, or if operation could only end in so much shortening that function would be irremediably lost, amputation is preferable, and it is useless to defer it.

(*f*) *A case is seen with a vicious callus.*—If the callus permanently interferes with walking, both bones must be re-fractured, and the misshapen callus must be cut away with chisel and mallet until the newly formed bone has been removed and reduction has become possible. When this has been done, tibial osteosynthesis is effected with a metal plate; the wounds are left open, without suture, and the leg is carefully immobilised in a posterior plaster splint: a very satisfactory result will generally be obtained (figs. 149 and 150).

B. Supra-malleolar Fractures. — 1. ANATOMICAL FEATURES.—According to my experience, there is usually one main line of fracture in the tibia, separating the epiphyseal end from the shaft. This is flanked either behind or in the space between the tibia and fibula by two or three scale-like fragments which may extend down into the ankle-joint. The line of fracture may be definitely transverse; more often, it is oblique antero-posteriorly and from above downwards. In these cases the lower fragment has a very sharp upper point, about 3 inches in length. It might be described as an incomplete spiral fracture. There is a comminuted fracture of the fibula without displacement of the small longitudinal splinters.

2. PHYSIOLOGICAL FEATURES.—In transverse fractures the foot is pulled backwards and upwards by

the gastrocnemius, soleus, and plantaris, and the shaft fragment projects forwards.

In oblique fractures the foot rotates backwards in the same way, and the lower fragment, the point of which forms a projection anteriorly, faces upwards and backwards, while the upper fragment is carried downwards and backwards by the action of the flexors of the foot. Lateral deviation almost always exists, but not in any constant direction.

FIG. 151.—Fracture of the lower end of the bones of the leg, with large oblique anterior tibial fragment, and small posterior fragment.

3. COURSE. — The gravity of these fractures is due to the possibility of secondary infection of the joint through radiating fissures, and also to the difficulty of reduction.

If the lesion becomes septic, arthritis of the ankle-joint is possible, and sometimes leads to amputation of the leg. Pus may also track along the tendon sheaths, and sometimes forms a prominence in the sole of the foot.

In the most simple cases a large deformed callus forms, and the position is bad.

In my opinion, these fractures, orthopædically speaking, and from the point of view of functional restoration, are, with the exception of those of both bones of the forearm, the most difficult fractures to treat.

Little control of the lower fragment is possible, and unless it is inadequately restored to its proper position, a curvature (concave posteriorly or anteriorly) with a considerable degree of pes equinus results. The latter

does not always affect function seriously, and may even sometimes be useful as in some degree compensating for the deformity from the static point of view, but good reduction is much preferable. There is almost always some degree of varus or valgus also.

Finally, when union has occurred, there is usually

FIG. 152.—Same case as fig. 151. After esquillectomy, and fitting a continuous extension apparatus (plaster with Delbet's rods), traction is still inadequate, and the fracture is not reduced.

FIG. 153.—Final result after three months of continuous extension. From the front the reduction seems perfect. Viewed laterally, slight rotation forward is still evident.

appreciable shortening and deformity, necessitating the wearing of an orthopædic boot.

4. INDICATIONS FOR EARLY TREATMENT. — The wound must be disinfected and the fracture reduced.

(*a*) *Disinfection* should be effected as soon as possible by esquillectomy. In these fractures, however, the splinters are not numerous. In transverse fractures two incisions are made, one on the internal aspect of the tibia, and the other over the fibula, and the lateral

fragments are removed. The fibula is shortened as may be necessary by sawing off enough of the supra-articular cancellous tissue to reduce it to corresponding dimensions with the tibia. When the fracture has been cleared in this way, its posterior aspect is examined ; it is not unusual to find small spicules of bone here which must be removed with great care. In

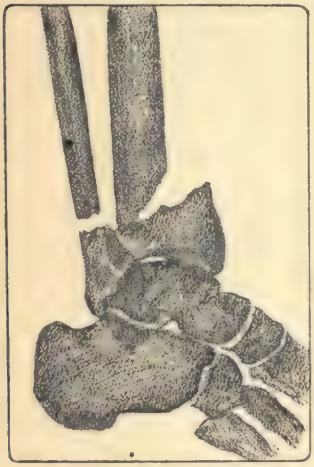

FIG. 154. — Infected supra-malleolar fracture. Radiograph after total sub-periosteal esquillectomy on the fourth day.

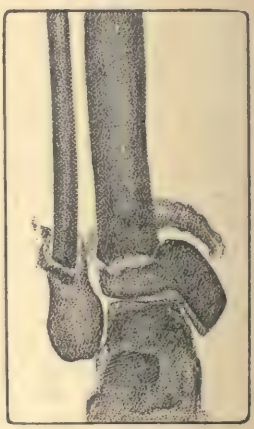

FIG. 155.—Result given by continuous extension after three months. Fracture united by a very translucent but resistant callus.

oblique fractures, part of the tapering extremity of the lower fragment must be removed, in order to expose the region well, and to explore it thoroughly. This has not appeared to me to facilitate its reduction.

(*b*) *Reduction* is very difficult, as no direct hold on the lower fragment is possible.

At first, post-operative manual reduction during anæsthesia is sufficient, with immediate application of plaster. But as soon as possible something better must be done : continuous extension is necessary,

but is inadequate if applied in the usual way. I have often exerted the pull through stirrups incorporated in the dressing, without ever succeeding in obtaining perfect correction. A better result is given by suspension, because less force is lost, and the traction is better utilised. Even this, however, is not ideal. Without experience of it, I am inclined to believe that extension by nail transfixion or the Finochietto stirrup is definitely indicated. The danger of infection will be urged against this, but it is not great, and the danger of non-reduction is certainly more urgent.

5. THE TREATMENT OF CASES SEEN AT A LATE STAGE OR AFTER PREVIOUS TREATMENT.—(*a*) *A case has done well without operation.*—In these cases, treatment should be directed solely to reduction and immobilisation. For this purpose I believe the best apparatus to be a suspension appliance, with traction by means of the Finochietto stirrup (figs. 33–35).

(*b*) *A case arrives with sepsis in the secondary period.*—Immediate esquillectomy, as described above, is necessary; it should be comprehensive, every effort being made to overlook nothing. Immobilisation should be based on the same principles.

When the injury to soft parts, tendons, muscles, and skin is too extensive, amputation may be justified, not because it is impossible to check the infection, but because a deplorable functional result is to be anticipated. Judgment is only possible in individual cases, and it is impossible to give a definite rule on the subject.

(*c*) *A case arrives with a sinus.*—Sometimes this is a simple matter, and the removal of a sequestrum is sufficient to effect cure. But much more often extensive clearance of the tibia is necessary, and even actual sub-periosteal resections of the shaft, in order to bring about recovery.

(*d*) *A case is seen with equinus.*—Some cases of this sort are compensating, and no interference should be attempted; value should be attached in these cases

rather to functional usefulness than to anatomical appearance.

Sometimes, when there is vicious or painful ankylosis, astragalectomy is indicated. On the other hand, this has little effect on a vicious callus, and under such circumstances direct operation on the region of the fracture is preferable. On several occasions I have performed double osteotomy in the fractured region, followed by osteosynthesis, with excellent orthopædic and functional results. This is the ideal treatment for a vicious callus.

II. Fracture of the Tibia

There are three types of fracture of the tibia alone :

Fracture of the upper end.
Fracture of the shaft.
Fracture of the lower end.

A. Extra-articular Fracture of the Upper End.—This is a fracture of a very special type. The superficial wound is small, but the cancellous tissue is extensively crushed by the projectile, close up to the articular cartilage. In a few days this contused cancellous tissue undergoes necrosis, and a foul form of sepsis develops which affects the joint ; in many cases amputation in the thigh becomes necessary.

When the infection is less violent, a chronic suppuration develops, with slow necrosis and gradual elimination of the cancellous tissue, which frequently ends in ankylosis of the knee and sinus-formation, or in pseudarthrosis.

Sometimes union occurs, but it is then almost invariably vicious, the lower fragment sliding backwards upon the upper and producing the deformity known as a " bayonet leg."

In short, therefore, this is a serious fracture. It should be treated by early, if not immediate, removal

of all contused cancellous tissue. For this purpose, the region must be widely exposed, if necessary by making a crucial incision, and freeing with a rugine the periosteum into which the patella tendon is inserted; the anterior wall of the fracture area is removed, and the cancellous tissue carefully cleaned with the curette until apparently healthy bone is encountered.

After this, the limb is immobilised in a plaster case which presses the lower fragment forwards. This arrangement is temporary only, and should be replaced later by a suspension immobilisation appliance (see fig. 140). Backward rotation of the lower fragment is thereby prevented by excluding muscular action.

The same treatment should be adopted as a *secondary measure*. The wound should then be left widely open, and any small fragments of bone remaining, which are usually eliminated by degrees, should be looked for; if necessary, occasional applications of the curette are made. The wound should then progress aseptically, but the healing, and the filling-up of the large cavity excavated in the cancellous tissue, must be closely attended to. Sometimes the latter may be plugged, and left exposed to the air and, particularly, to the sun. Recovery takes three to four months.

A sinus is treated by opening up widely; in certain cases a large cavity will be found in the epiphysis, and resection of the head of the bone will be necessary. The cartilaginous surface of the femoral condyles is removed, and the surfaces of the femur and tibia are nailed together as after a typical resection. It will be necessary to cut a groove in the external condyle, for the head of the fibula.

Pseudarthrosis necessitates a freshening of the bone ends in the case of the tibia, and removal for adaptive purposes in the fibula. Fixation of the fragments of the tibia is necessary; I have twice performed it successfully at the fistulous stage.

B. Fractures of the Shaft.—There are many lateral

wounds of the tibia, with fissures radiating beneath the periosteum, but with no true fracture. Complete fractures without injury to the fibula are uncommon. The fracture is hence almost always one with large diamond-shaped splinters, more or less disposed in the classical "butterfly-wing" manner, or as a spiral fracture. There is usually very little displacement, the fibula being intact.

The course of these fractures is identical with that of fractures of the leg, in which the tibial element is much the more important: grave infection, acute osteomyelitis, diffuse cellulitis of the calf, and later, chronic osteomyelitis, suppuration, and sinus-formation. Owing to the elimination of sequestra, it is not unusual to see union fail to occur, the fibula acting as a rigid support, and keeping the fragments of the tibia apart.

The first step is free esquillectomy, the periosteum being preserved. Subsequent treatment is conducted as already described. Immobilisation is effected by a simple plaster trough. Any extension appliance is useless, because the fibula is intact.

If esquillectomy has left an appreciable inter-fragmentary gap, and if this still appears considerable in a radiograph after three or four weeks, an adaptive resection of a sufficient length of the fibula ($\frac{1}{2}$ to 1 inch) is carried out as a precaution to prevent pseud-arthrosis.

C. Fracture of the Lower End.—Isolated fractures of the internal malleolus are sometimes seen, with fissures, and often detachment of splinters, both involving the joint. If the fracture continues aseptic, the articular lesion is unimportant. If the infection is superficial, slight arthritis develops, which almost always ends in ankylosis of the ankle-joint. Sometimes the infection is deeper, and suppurative arthritis develops; this is exceedingly rare, and the cases which are being discussed here should be clearly distinguished

from definitely articular wounds, complicated by a malleolar fracture, which are discussed in Vol. I, p. 174.

In isolated fractures of the tibial malleolus, limited esquillectomy is usually sufficient: the early removal of the small splinters and the fragment which extends into the joint, ensures an uneventful development of the fracture. Cure is complete in about forty days.

On the whole, this fracture is not a severe one.

III. Fracture of the Fibula

Three types may be distinguished in practice:

Fracture of the head and neck.
Fracture of the shaft.
Fracture of the malleolus.

A. Fractures of the Head and Neck.—These are generally fractures by crushing of the cancellous tissue, with one or two small compact splinters at the point of junction with the shaft.

There is no displacement, in spite of the presence of the biceps tendon, but the external popliteal nerve is frequently involved.

Being very superficial, the fracture is not complicated by serious septic conditions, and the vicinity of the knee-joint is of no practical importance. But as cancellous tissue is concerned, it is usual for osteitis to continue indefinitely, delaying a final cure, while the infection, giving rise to the formation of scar tissue, reacts seriously on, and sometimes causes secondary paralysis of, the neighbouring external popliteal nerve. Cure often occurs after elimination of a considerable part of the bone, but the loss of bone-substance caused in this way has no effect on equilibrium. Prolonged suppuration, however, lays up the patient for a considerable period.

It would therefore appear advisable, as soon as the case has been examined, to perform total sub-periosteal

esquillectomy. This operation need only be a resection in exceptional cases: resection, in fact, would inevitably open the upper tibio-fibular joint, and this, in about 12 per cent. of cases, communicates with the synovial cavity of the knee-joint. A risk would therefore be run, which it is better to avoid. Esquillectomy is performed by means of an incision which at once exposes the external popliteal nerve, in order to safeguard it from injury. The incision should be made, not directly over the bone, but posterior to it, along the biceps tendon, which forms an obvious prominence beneath the skin. The incision is begun about an inch above the head, and directed along the bone in such a way as to correspond with the interstice between the soleus and the peronei muscles. When protection of the nerve has been ensured, esquillectomy is carried out as usual, with a rugine.

FIG. 156.—Fracture of the fibula, with osteitis of the whole head of the bone, and secondary paresis of the external popliteal nerve. Complete secondary resection of the head of the bone was necessary.

The operation over, immobilisation for a few days is advisable, without plaster or splint.

The subsequent course is usually uneventful; treated in this way, these fractures are almost featureless.

B. Fractures of the Shaft.—Either the fracture is comminuted, or it has short fragments and radiating fissures. Owing to the laceration of neighbouring muscles, this very simple fracture should be treated as rigorously as any other, in order to avoid the tracking

of pus, cellulitis of the calf, secondary hæmorrhages, etc., which develop when any wound or fracture, whatever its initial appearance, is not systematically cleaned. Esquillectomy should therefore be performed at once, the bone being exposed by an external incision over its prominence, and all the splinters removed after being separated from the periosteum. A careful search is made for the smallest fragments of bone, which are often driven into the calf muscles: I have several times found them between the peroneal and posterior tibial vessels. This avoids subsequent vascular complications, which otherwise occur frequently, and the simplicity and rapidity of healing will cause surprise. I have seen the periosteum form a column of new bone uniting the two fragments. I have also seen regeneration fail to occur, but this is of no practical importance.

At a later stage the same methods should be applied: phlegmon of the calf, which is the usual evidence of infection of the fractured region, is very rapidly checked by these means. Unless speedy action be taken, there is prolonged suppuration, followed by lardaceous sclerosis of the calf-muscles—with secondary equinus—necessitating orthopædic corrections at a late stage which are often difficult. In pes equinus due to muscular contracture, lengthening of the tendo Achillis by a Z-shaped incision gives little result: it is better to shorten the skeleton, and adapt it to the muscular retraction by performing astragalectomy. Quite recently I have performed temporary astragalectomy for cases of this kind, sawing through the bone horizontally, and immediately replacing the upper half of it: the results have been perfect; the movements of the ankle-joint have been entirely recovered, and the length of the limb has only been reduced by half an inch.

C. Fracture of the Malleolus.—These fractures are usually not serious. This is fortunate, since preserva-

tion of the external malleolus is essential for the satisfactory equilibrium of the foot. These fractures should be clearly distinguished from intra-articular fractures of the astragalus complicated by injury to the external malleolus.

The limited esquillectomy which is necessary is usually sufficient to ensure an uneventful course.

If there is slight articular infection, simple immobilisation may be sufficient; but there should be no hesitation in doing astragalectomy in the event of an acute septic condition.

CHAPTER VIII

MULTIPLE FRACTURES OF THE LOWER LIMB

These are not uncommon: they call for rigorous application of the principles laid down for each variety of fracture considered separately—that is to say, immediate sub-periosteal esquillectomy, primary or secondary, according to when the case is seen. The necessity for esquillectomy is more pressing in these complex cases than in any others.

The only really difficult problem presented by these fractures is that of immobilisation. Temporarily, and as an appliance for transport, plaster is the best medium; but as soon as possible, recourse should be had to a suspension appliance, either extending the entire lower limb, or, better, arranging the thigh in flexion on the pelvis, and the leg in flexion on the thigh. It is easy in the latter case to apply a double extension, one to the thigh and the other to the leg (see fig. 142).

Double fractures of a bone should be treated on similar lines, and a useful limb can be preserved by esquillectomy even in the most complex cases. I have personally treated and cured a double fracture of the femur by double sub-periosteal esquillectomy, and a bipolar fracture of the bones of the leg by resection of the knee above and esquillectomy below. The case was cured with a shortening of $2\frac{1}{2}$ inches.

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